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Volume 23 APRIL 29, 1948 Number 3

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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

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PROGRAMME OF THE

WASHINGTON MEETING

AT

WASHINGTON, D. C.

April 29–30, May 1, 1948

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PUBLISHED BY THE AMERICAN PHYSICAL SOCIETY
SIX ISSUES EACH YEAR

BULLETIN

of the

AMERICAN PHYSICAL SOCIETY

Published six times per year

Subscription price: $5.00 per year

Single copies: $1.00 each

The Bulletin of the American Physical Society is published six times a year, twice in January, once in April, twice in June, and once in November, at Prince and Lemon Streets, Lancaster, Pennsylvania.

Address correspondence to Prince and Lemon Streets, Lancaster, Pa., or to Secretary Karl K. Darrow, Columbia University, New York 27, New York.

Entered as second class matter, November 25, 1947, at the post office at Lancaster, Pa. under the Act of August 24, 1912.

Acceptance for mailing at a special rate of postage provided for in the Act of October 3, 1917, embodied in paragraph 4, Section 412, P. L. & R., authorized April 28, 1928.

APRIL 29, 1948 Vol. 23, No. 3

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

WASHINGTON MEETING, APRIL 29–30, MAY 1, 1948

THE **Spring Meeting of the American Physical Society,** held again at Washington as it was last year and before the war, will very completely fill the days of Thursday, Friday, and Saturday, April 29 and 30 and May first, 1948. (**To insure yourself a place at the important dinner, read on to the relevant paragraph on page 4 and act accordingly!**) This meeting will set a record, with 226 (!) contributed papers and twenty-eight invited papers—and this without the aid of any organized programmes of our Divisions! Our members will discover that even Washington has handicaps as a meeting place for meetings of the size of ours: they will have to look for the various sessions at various institutions, one of them not even within walking distance of the others. Our principal host is George Washington University, where the **registration desk** will be located: there will be sessions also at the National Bureau of Standards, at the National Academy of Sciences, and in two Government auditoriums which we obtain because the Navy is co-sponsor of two of our symposia. **Bring your Bulletin with you to minimize waste of copies.**

Location of the meeting rooms. The Secretary last year overlooked the fact that nearly half of the members of the Society have joined it since the last pre-war meeting in Washington, so that even such institutions as the National Academy of Sciences and the National Bureau of Standards are unfamiliar to many. George Washington University (containing the Lisner Auditorium and the Hall of Government) extends along 21st Street, the Lisner Auditorium being at 21st and H and the Hall of Government at 21st and G Streets. The National Academy of Sciences is at 2101 Constitution Avenue, southward from the University. The Department of Interior Auditorium is on C Street between 18th and 19th; the Department of Commerce Auditorium is on 14th Street between E Street and Constitution Avenue. The National Bureau of Standards is on the west side of Connecticut Avenue at Van Ness Street; the buses marked L-2 and L-4 start from the corner of 13th Street and Pennsylvania Avenue, making the distance in half-an-hour. (For completeness the letters N.W. should be suffixed to all the street names given above.)

The **registration desk** will be in the Lower Lobby of the Lisner Auditorium. Even those whose interests call them to other buildings exclusively are asked to register there.

A Symposium on Radiofrequency and Microwave Spectroscopy, under the joint sponsorship of the United States Navy and the American Physical Society, will be held on Friday morning and Friday afternoon in the Department of Interior Auditorium, and will continue on Saturday morning in the Department of Commerce Auditorium. This vast and variegated complex of subjects, poorly described by this or any other name, includes such topics as molecular-beam experiments of the types associated with the name of Rabi, precise measurements of the magnetic moment of the electron, magnetic resonance experiments on liquids and solids, and diverse information on molecular structure and band-spectra. Columbia University considers that "radiofrequency" subsumes "microwave," Massachusetts Institute of Technology considers

APR 19 1948

that these words refer to different spectrum ranges: the Secretary takes no side in this issue, but adopts sometimes one usage and sometimes the other.

A Symposium on Computing Machines, under the joint sponsorship of the United States Navy and the American Physical Society, will be held on Saturday afternoon in the Department of Commerce Auditorium.

The **National Bureau of Standards presents a group of six papers** by members of its staff, all pertaining to basic physical measurements made at this notable institution: they will be presented on Friday afternoon in the Lecture Room of the East Building of the Bureau, formerly familiar to our older members but now completely renovated and improved.

Invited papers on the general programme comprise: accounts of recent work at the Radiation Laboratory at Berkeley, to be given on Thursday morning in Lisner Auditorium by E. M. McMillan and Emilio Segrè; a paper on the magnetization of ancient glacial varves, to be given on Thursday morning at the National Bureau of Standards by E. A. Johnson; a paper on meson production, to be given by W. Heitler on Saturday morning in Lisner Auditorium; and by R. A. Millikan, whose eightieth birthday will be celebrated by various meetings at Pasadena in June, an address under the title "Why My Stork Chose 1868," in the Lisner Auditorium at 2:15 on Thursday afternoon.

The **distribution of the 226 contributed papers** is indicated in the schedule printed farther along in this Bulletin. It will be sadly noted that even nuclear physics by itself has become so voluminous that it was impossible to avoid simultaneous sessions within this field. Gone are the days (if they ever existed) when the members could leave Washington before Saturday afternoon without missing anything important!

The **banquet of the American Physical Society** will be held on Thursday evening, April 29, in the Sapphire Room of the Mayflower Hotel. At this banquet the British Ambassador, Lord Inverchapel, will be present and will present the Duddell Medal of the Physical Society of London to our fellow-member R. J. Van de Graaff. R. W. Wood (whose eightieth birthday falls on May 2) will give an after-dinner speech. Chamber music will follow the dinner. The price is $5.00 per plate, and our members are urgently requested to send not only letters of reservation, *but their checks*, to Mr. Hugh Odishaw at the National Bureau of Standards, Washington 25, D. C. A form is provided on the inside back cover page of this Bulletin to accompany the checks. Probably a few tickets will be provided for sale at the registration desk, but our members should not count on them. The officers of the Society lost a large part of the New York meeting watching over the progress of ticket sales at the desk, in order to match the guarantee with the sales: they do not intend to repeat this sacrifice.

The **Sigma Pi Sigma luncheon** will be held at 12:30 P.M. on Friday in the Roger Smith Hotel (18th and Pennsylvania) at the price of $1.50—write preferably in advance to Dr. Marsh W. White, State College, Pennsylvania; tickets not bespoken in advance will be available at the registration desk up to 10 o'clock on Friday morning.

The **Council of the American Physical Society** will meet at 7:30 o'clock on Friday evening, in a room off the Lower Lobby of Lisner Auditorium, unless contrary notice is sent to its members.

The **Nominating Committee of the American Physical Society** (L. A. DuBridge, *chairman*; H. L. Dryden, J. R. Dunning, F. G. Dunnington, G. F. Hull Jr., H. M. James, W. Shockley, J. T. Tate, J. H. Van Vleck) will meet at 5:00 P.M. on Friday in Room 301, South Building, National Bureau of Standards.

Feminine members of the Society and wives of its masculine members will be greeted by Mrs. Truman at the White House on Thursday afternoon at half-past three o'clock. To be admitted to this event, those who are eligible must write to Mrs. F. G. Brickwedde, National Bureau of Standards, Washington 25, D. C., who must receive their letters (*print* the names, please!) not later than April 27. Personal admittance cards prepared by the White House will be given out

at the registration desk up to three o'clock on Thursday afternoon. "Requests should be made only for those who are reasonably certain of attending, since the number is limited."

Hotels. A large number of rooms was guaranteed to our members by the Raleigh, Shoreham, Wardman Park, Washington and Willard Hotels. This is mentioned for the sake of the record chiefly: by the time this Bulletin appears, these rooms should all be booked, and dilatory members ought not to be surprised if they have to seek elsewhere.

Post-deadline papers. This item is without precedent: the Council, availing itself of an amendment to the By-Laws adopted on January 30, announces that "The Council or its designates will consider the admission, to a special supplementary programme, of a limited number of additional papers of which the abstracts reach the office of the Society not later than Friday 23 April." Do not regard this as a guarantee! the idea is to make possible the presentation of a small number of very recent achievements of very special importance. The abstracts of the post-deadline papers which are thus accepted (if any are) will not be published. They will probably be scheduled for Saturday afternoon in the National Academy of Sciences.

Prospective meetings of the Society are planned as follows: Madison, Wisconsin, June 21–23; Pasadena, California, June 24–26.

General Rules Relating to Papers

The time allowed for the oral presentation of a contributed paper is ten minutes at most. The time allowed for the oral presentation of an invited paper is stated in the Bulletin.

When two or more papers are contributed by the same member, all but one are placed on the "supplementary programme." (A paper by two or more members is credited, for this purpose, to the person first named in its by-line.) For each paper on this programme a session is indicated, at the end of which it may be offered: but the presiding officer of the session may require that it be given in fewer than ten minutes, or may read it by title.

Titles and abstracts of the papers contributed to the Washington meeting of 1948 are given in the following pages. Proofs of the abstracts have not been submitted to the authors, and the proofreading is always cursory because of the need for haste; but the authors have opportunity to correct their proofs before the abstracts appear in the *Physical Review*. Overlong abstracts sometimes appear in a form unexpected by the authors, because there is not time to consult them before amputating the abstracts to fit the requirements stated on the summons card.

Karl K. Darrow, *Secretary*
American Physical Society
Columbia University
New York 27, New York

EPITOME OF THE PROGRAMME

Thursday Morning

A. E. M. McMillan, Emilio Segrè; nuclear scattering. Lisner.
B. E. A. Johnson; ferromagnetism and photoconductivity. Bureau.
C. Atomic spectra and x-rays. Hall of Government, Room 1.
D. Gases at microwave frequencies; magnetic resonance. Hall of Government, Room 102.
E. Theoretical physics. National Academy.

Thursday Afternoon

EA. R. A. Millikan; cosmic rays. Lisner.
F. Neutrons. Hall of Government, Room 102.
G. Solid-state physics including semi-conductors. Bureau.
H. More or less thermal; also, mass-spectra of ions. Hall of Government, Room 1.
I. Theoretical and experimental nuclear physics. National Academy.

Friday Morning

J. Reactions of transmutation, I. Lisner.
K. Fluid dynamics and ultrasonics. Hall of Government, Room 102.
L. Diverse topics. Bureau.
M. Symposium on radiofrequency and microwave spectroscopy: K. K. Darrow, W. E. Lamb, Jr., P. Kusch, John Nafe. Interior.

Friday Afternoon

N. Symposium on radiofrequency spectroscopy, continued: J. R. Zacharias, Hans Staub, R. V. Pound, Francis Bitter, H. L. Anderson. Interior.
P. Reactions of transmutation, II. Lisner.
Q. Cryogenics. Hall of Government, Room 102.
R. Basic physical measurements (invited papers). Bureau.

Saturday Morning

S. Mesons artificial and natural. Lisner.
T. Artificial radioactive substances, I. Hall of Government, Room 102.
U. R. L. McCormack, J. Cardwell, W. B. Nottingham, L. Pensak; phosphors. Bureau.
V. Symposium on radiofrequency spectroscopy, concluded: P. R. Weiss, Charles Kittel, D. K. Coles, M. W. P. Strandberg, C. H. Townes, E. Bright Wilson. Commerce.

Saturday Afternoon

W. Symposium on computing machines; Howard Aiken, R. L. Snyder, W. J. Eckert. Commerce.
X. Apparatus of nuclear physics. Lisner.
Y. Molecular structure and nuclear moments. Hall of Government, Room 102.
Z. Artificial radioactive substances, II. Hall of Government, Room 1.
ZZ. Post-deadline papers, if any. National Academy.

PROGRAMME

THURSDAY MORNING AT 10:30

Lisner Auditorium

(E. O. LAWRENCE presiding)

Invited Papers

A1. A Survey of Recent Work at the Radiation Laboratory in Berkeley. E. M. MCMILLAN, *University of California, Berkeley.*

A2. Experiments on High-Energy Neutron-Proton Scattering. EMILIO SEGRÈ, *University of California, Berkeley.*

Contributed Papers on Nuclear Scattering

A3. Proton-Proton Scattering: 2.4 to 3.5 Mev. J. M. BLAIR, WILLIAM SLEATOR, JR., GEORGE FREIER, E. E. LAMPI, AND J. H. WILLIAMS, *University of Minnesota.**—The experiments on the differential cross section for proton-proton scattering reported at a previous meeting[1] have been completed, extending the measurements to higher energies. The dimensions of the apparatus, the current collection system, etc. have been recalibrated, and considering the probable errors in these measurements and the internal consistancy of the scattering data, it is believed that the probable errors in the absolute cross sections are 1.6 percent. At the lowest energy where these measurements overlap those of Herb[2] our values deviate from theirs, in the region from 20° to 45°, by ½ percent. Proton-proton cross section per unit solid angle (in barns) angles given in laboratory system, energies in Mev:

energy	8°	10°	12.5°	15°	17.5°	20°	25°	30°	35°	40°	45°
2.43	8.12	3.09	1.35	.804	.631	.564	.528	.528	.503	.475	.443
3.05	5.03	2.01	.969	.640	.623	.539	.494	.483	.469	.450	.425
3.26	4.47	1.79	.869	.605	.513	.479	.473	.450	.441	.410	.380
3.50	3.72	1.55	.778	.548	.474	.463	.442	.428	.418	.397	.366

* The research described in this abstract was supported in part by the Office of Naval Research.

[1] Sleator, Blair, Lampi, and Williams, Bull. Am. Phys. Soc. Jan. 1948, p. 9.

[2] Herb, Kerst, Parkinson, and Plain, Phys. Rev. **55**, 998 (1939).

A4. Analysis of Proton-Proton Scattering.—CHARLES L. CRITCHFIELD, *University of Minnesota.*—The experimental results of Blair, Sleator and Williams on the scattering of protons in hydrogen have been analyzed. Provisional values of the S-wave "phase-shifts" K_0, due to nuclear forces, as determined from the scattering observed in the range of laboratory angles, 20 to 45 degrees, are shown in Table I. Small deviations from the formula for the differential cross section that includes only the S-wave anomaly occur at small angles of scattering and will be discussed with reference to uncertainties in corrections, relativistic effects and possible P-wave effects.

TABLE I.

Energy	2.432	3.047	3.259	3.501	Mev
K_0	48.6	51.0	51.8	52.4	degrees

A5. On the Neutron-Proton Force.—JOHN M. BLATT, *M.I.T.*—Neutron-proton scattering experiments[1] below 10 Mev were analyzed using Schwinger's theory[2] which describes the force phenomenologically by the scattering length a[3] which it causes, and by its *effective range* r (depending both upon the wellrange and welldepth). a_t and r_t (triplet state) are related through the deuteron binding energy; a_s and r_s are independent. Scattering data give two relations between r_t and r_s. Unfortunately these two relations overlap completely, so one can't find either r_t or r_s. The coherent scattering amplitude $f=2(0.75a_t+0.25a_s)$ and the epithermal cross section determine r_t uniquely. f is measured by neutron scattering from parahydrogen[4] and hydrogen-containing crystals.[5] The crystal measurement contradicts the parahydrogen measurement and the scattering data. The parahydrogen measurement and the scattering data contradict the hypothesis of the charge independence of nuclear forces in a given spin-state. A redetermination of f is strongly recommended.

[1] C. L. Bailey *et al.*, Phys. Rev. **70**, 583 (1946). D. Frisch, Phys. Rev. **70**, 589 (1946).

[2] J. Schwinger, unpublished.

[3] E. Fermi and L. Marshall, Phys. Rev. **71**, 66 (1947).

[4] R. B. Sutton *et al.*, Phys. Rev. **72**, 1147 (1947).

[5] G. C. Shull *et al.*, Phys. Rev. **73**, 262 (1948).

A6. Elastic Scattering of Protons by Aluminum in the Neighborhood of the 985 Kev Resonance. R. S. BENDER,* F. C. SHOEMAKER, S. G. KAUFMANN, AND G. M. B. BOURICIUS, *University of Wisconsin.*—According to the Breit-Wigner theory of nuclear resonances, there should be an anomalous variation of the cross section for elastic scattering of protons in the neighborhood of a resonance level. To observe this effect, the energy spread of the proton beam and the absorption thickness of the target should approximate the resonance width, less than 300 volts for the 985 kev aluminum level. The Wisconsin pressure generator and electrostatic analyzer[1] were used to obtain protons of the desired mean energy and energy spread. The targets were made by evaporating aluminum onto a pure carbon block. Since carbon nucleii are lighter than those of aluminum, protons elastically scattered by the aluminum have higher energy. A magnetic analyzer

thus allowed only those protons scattered by aluminum to enter the proportional counter. The scattering angle was 165°. Runs were taken, counting both protons and gamma radiation, with different target thicknesses and beam spreads. The general form of the anomaly agrees with the theory, but the analysis of the data is as yet incomplete.

* Now at the University of Pittsburgh.
[1] R. E. Warren, J. L. Powell, and R. G. Herb, Rev. Sci. Inst. **18**, 559 (1947).

A7. A New Method of Studying Nuclear Energy Levels.* H. W. FULBRIGHT AND R. R. BUSH, *Princeton University.*—A technique has been developed for performing scattering experiments inside the dee chamber of the Princeton 35-inch single-dee synchro-cyclotron. A small scattering camera which rests on the floor of the chamber supports the scattering foil The foil is a narrow vertical strip which intercepts the undeflected beam. Those particles scattered slightly doward follow helical paths of small pitch; some of them pass through a vertical slit and strike a horizontal photographic plate. The energy of the particle which produces a given track in the plate can be deduced from the position of the track, the strength of the magnetic field, and the geometry of the camera. Actually, distinct lines easily seen by the unaided eye are obtained from elastically and inelastically scattered protons with exposure times of about thirty minutes. The sharpness of the lines shows that the energy spread of the cyclotron beam at any of the radii used is probably less than 0.1 Mev. A wide range of incident energies and scattering angles has been covered by placing the camera in different positions. Results obtained will be described in the following paper.

* This work was supported in part by Navy contract.

A8. Nuclear Energy Levels from Inelastic Scattering of Protons.* R. R. BUSH AND H. W. FULBRIGHT, *Princeton University.* By means of the method just described, protons of 6.7, 10.5, and 17.0 Mev have been scattered from magnesium, aluminum, and iron. Natural magnesium which is 77.4 percent Mg^{24} showed levels at 1.2, 1.7, 2.7, 4.6, 6.0, 8.1, and 9.2 Mev above the ground state. These energy values are believed to be accurate within ±0.3 Mev, except those at 2.7 and 9.2 Mev which are within ±0.5 Mev. The 2.7 Mev line is weak; the others are approximately as intense as the elastic line for large scattering angles. The 4.6 and 6.0 Mev lines show a marked variation of intensity with scattering angle. Possible alternate reactions involving the emission of deuterons and alpha-particles were considered and ruled out. The fact that Mg^{25} and Mg^{26} are low in abundance suggests that all the levels listed, except possibly that at 2.7 Mev, are levels of Mg^{24}. Results obtained from aluminum and iron will also be discussed.

* This work was supported in part by Navy contract.

A9. Neutron Helium Resonance Scattering. L. EISENBUD, *Brookhaven National Laboratory.*—An analysis of the data of Hall and Koontz* on the angular distribution of neutrons scattered by He for neutron energies between 0.8 and 1.6 Mev has been undertaken to determine the character of the levels of He^5. The analysis was made in terms of a generalized one level formula.** If it is assumed that the scattering is largely due to the presence of a $P_{1/2}$ and a $P_{3/2}$ level, the data requires that the $P_{3/2}$ level be at about 1.2 Mev, and the $P_{1/2}$ at about 1.6. This order of the levels is difficult to understand on theoretical grounds. Moreover the constants required for the fit to the data lead to the conclusion that the *distribution* of $P_{1/2}$ levels is quite different from that of $P_{3/2}$ levels and this throws doubt on the validity of the description obtained. The general behavior of the angular distribution functions may also be explained on the assumption of a low lying $P_{1/2}$ level (<0.5 Mev), a $P_{3/2}$ level at 1.2 Mev and an $S_{1/2}$ level at about 1.6 Mev. This order of levels seems more satisfactory on the basis of internal consistency but leads to difficulty in connection with the proton, helium scattering. Research carried out at the Brookhaven National Laboratory under the auspices of the Atomic Energy Commission.

* T. A. Hall and P. G. Koontz, Phys. Rev. **72**, 196 (1947).
** E. P. Wigner and L. Eisenbud, Phys. Rev. **72**, 29 (1947).

THURSDAY MORNING AT 10:30

East Building Lecture Room

National Bureau of Standards

(R. SMOLUCHOWSKI presiding)

Invited Paper

B1. Magnetization of Ancient Glacial Varves. E. A. JOHNSON, *Department of Terrestrial Magnetism.* (25 min.)

Ferromagnetism and Photoconductivity

B2. Effect of Surface Treatment on Complex Permeability. G. T. RADO, M. MALOOF, AND H. ROSENBLATT, *Naval Research Laboratory.*—Using the method previously described[1] the complex permeability ($\mu=\mu_1-i\mu_2$) of iron and nickel as a function of a polarizing magnetic field (H_0) was measured at 200 mc/sec. and at 975 mc/sec. In

agreement with our previous observations[2,3] the high frequency permeability is nearly constant for polarizing fields below the knee of the magnetization curve. For sufficiently large H_0, moreover, μ_1 agrees with the static incremental permeability (μ_{stat}) measured on the same sample which was used for the high frequency tests. Iron and nickel differ both in the character of the dispersion and in the effect of surface treatments on μ. For untreated nickel, unlike untreated iron, the value of H_0 necessary to reduce μ_1 to unity is much larger than that required for static saturation. If, however, the surface is polished and the sample subsequently reannealed, the above mentioned agreement between μ_1 and μ_{stat} is obtained. The results will be discussed in terms of the mechanisms of magnetization underlying the various theories of ferromagnetic dispersion.

[1] M. H. Johnson, G. T. Rado, M. Maloof, Phys. Rev. **71**, 472(A) (1947).
[2] G. T. Rado, M. H. Johnson, M. Maloof, Phys. Rev. **71**, 472 (A) (1947).
[3] M. H. Johnson, G. T. Rado, M. Maloof, Phys. Rev. **71**, 322 (1947).

B3. Barkhausen Noise in Ferromagnetic Electrical Circuit Elements. R. T. BEYER AND J. A. KRUMHANSL, *Brown University.*—The voltages induced by Barkhausen effects in the ferromagnetic core materials of electrical circuit elements are treated as random processes. It is assumed that statistical behaviors throughout the core are identical, furthermore, that all domains have the same magnetic moment and are oriented either parallel or antiparallel to the core axis. Average values and mean square fluctuations of induced voltages, together with a description of the noise spectrum are obtained. Application is made to the calculation of the limiting sensitivity of magnetic amplifiers.[1] In this connection some theory of operation of magnetic amplifiers is presented. For the case considered, it is assumed that the signal windings of the magnetic amplifier transformers are not loaded appreciable, so that the resulting calculation refers to open circuit noise.

[1] H. S. Sack, R. T. Beyer, G. H. Miller, and J. W. Trischka, Proc. I.R.E. **35**, 1375 (1947).

B4. Theory of the Ferromagnetism of Simple Tetragonal Arrays. CHARLES KITTEL, *Bell Telephone Laboratories.*—The theory of the ferromagnetic properties of three-dimensional tetragonal lattices is of particular interest because the two limiting cases are believed to be essentially non-ferromagnetic. Let J_a, J_c denote the exchange integrals between nearest neighbors along the a and c axes, respectively; when $J_a/J_c \gg 1$ the lattice may be considered as a series of independent plane lattices, while $J_a/J_c \ll 1$ represents independent linear chains. A quantum-mechanical spin-wave treatment shows that the Bloch expression for the magnetization of a simple cubic lattice $I_s/I_0 = 1 - 0.117(kT/J)^{\frac{1}{2}}$ becomes $1-[0.117(kT)^{\frac{1}{2}}/J_c^{\frac{1}{2}}J_a]$ in the tetragonal case, so that qualitatively it appears that the Curie temperature may perhaps be proportional to $J_a^{\frac{1}{2}}J_c^{\frac{1}{2}}$ or, in the rhombic case, $J_a^{\frac{1}{2}}J_b^{\frac{1}{2}}J_c^{\frac{1}{2}}$. For a *simple* hexagonal lattice $I_s/I_0 = 1-[0.068(kT)^{\frac{1}{2}}/J_c^{\frac{1}{2}}J_a]$; similar structures occur in several ferromagnetic manganese compounds and in several magnetically-concentrated salts of the iron group which show some ferromagnetic features at low temperatures.[1] The above expressions suppose that the J's are positive; anisotropy effects are not considered separately.

[1] B. H. Schultz, Thesis, Leyden, 1940.

B5. Double Transmission and Depolarization of Neutons. M. BURGY, D. J. HUGHES, AND J. WALLACE, *Argonne National Laboratory.*—As described in earlier reports the production of polarized neutrons was measured by means of the "single transmission effect" which is the relative increase in transmission of an iron block when magnetized. The single transmission effect is simply related to the amount of polarization in the transmitted beam. Recently a series of measurements have been made concerning "double transmission effects" and depolarization of neutron beams. The measurements are made by passing a neutron beam through two blocks of iron, the first block acting as the polarizer, the second as the analyzer. The change in intensity of the transmitted beam with reversal of magnetization in the analyzer is called the double transmission effect. The large effects predicted by theory have been obtained but only when the fields between the magnets are carefully adjusted so that the neutron spin alignment is maintained. Depolarization of neutron beams by unmagnetized iron has been measured by placing thin sheets (of the order of 10^{-3} cm in thickness) of various iron samples between the magnets. The depolarization results give the domain sizes directly and domains ranging from 10^{-3} cm to 7×10^{-5} cm (the latter in severely cold worked material) have been observed.

B6. Neutron Polarization. J. STEINBERGER AND G. C. WICK.—In view of the discrepancy existing between experimental results[1] and theoretical predictions[2] on the polarization cross section p of iron for neutrons, a critical revision has been made of various factors: (a) the coherent nuclear cross section of Fe is about 50 percent larger than previously assumed, (b) the form factor for the d shell may also be larger, especially for Bragg reflections of higher order, (c) while the decrease in the Bragg scattering due to thermal agitation (Debye-Waller factor) has been taken into account, the inelastic diffuse scattering that accompanies it has been neglected so far, although it gives a non-negligible polarization effect.[3] Finally: (d) the assumption that the microcrystals are oriented at random is unjustified in cold rolled materials. When all these corrections are taken into account, the conclusion is reached that there is no serious evidence of any disagreement between theory and experiment.

[1] D. J. Hughes, Bul. Am. Phys. Soc. **22**, 18 (1947).
[2] O. Halpern, M. Hamermesh, and M. H. Johnson Phys. Rev. **59**, 981 (1941); M. Hamermesh, Phys. Rev. **61**, 17 (1942).
[3] O. Halpern, Phys. Rev. **72**, 260 (1947).

B7. The Spectral Emissivity of Iron and Cobalt. H. B. WAHLIN AND HARRY KNOP, *University of Wisconsin.*—The variation of the spectral emissivity for λ6690A has been determined as a function of the temperature. Sharp changes have been found in iron at the A_3 and A_4 points, and a less sharp change between these two points. In

cobalt a change has been found at the Curie point. An iron-cobalt alloy also shows changes.

B8. The Photoconductivity of Silver Chloride and Thallium Bromide in the Visible and Near Infra-Red.* WALLACE C. CALDWELL** AND LLOYD P. SMITH, *Cornell University.*—The photoconductivity of silver chloride and thallium bromide crystals increases as the light wave-length decreases from 1.0 to 0.35 micron. Below saturation voltage the photoconductivity of either crystal can be enhanced by exposure to ultraviolet light. Photoconductivity measurements on silver chloride after annealing the crystal in air shows some structure at 0.39 micron. After annealing the crystal in a chlorine atmosphere this structure nearly disappears. Enhancement of photoconductivity by ultraviolet is less for the chlorinated sample. When silver specks are formed in silver chloride, a broad photoconductivity band develops the onset of which is at 0.95 micron. Thallium bromide annealed in air has a sharp photoconductivity peak at 0.44 micron. Possible *mechanisms* for the above effects will be discussed.

* Work partially supported under a contract with the Office of Naval Research.
** National Research Council Predoctoral Fellow. Now at Iowa State College.

B9. Effects of Chlorine and Sulphur on Photoconductivity in Silver Chloride.* FLOYD R. BANKS, JR., *Polytechnic Research and Development Company.*—Silver chloride crystals have been tempered for various times in atmospheres of chlorine and sulphur, and annealed at the rate of 18°C per hour. The effect of chlorine is to suppress greatly the photoconductivity in silver chloride. Thus, samples heated at 430°C for 50 hours in chlorine (760 mm pressure at room temperature) have a photoelectric response in the spectral region surveyed (0.38 to 2 microns) approximately one-thousandth of that for silver chloride tempered in air at the same temperature for 24 hours and annealed at the same rate. Silver chloride heated in evacuated containers with varying amounts of sulphur (from 0.05 percent to about 100 percent by weight), tempered at 430°C for three hours and annealed, shows a photoelectric response analogous to silver sulphide. Peak photoelectric currents of about 0.1 microamperes at approximately 1.2 electron volts are obtained. Silver chloride tempered at 430°C for various times in evacuated containers and annealed has increased low temperature dark conductivity (compared with samples tempered in air) and reduced (by about 200) photoelectric response.

* Supported by the Office of Naval Research.

THURSDAY MORNING AT 10:30

Hall of Government, Room 1

(W. F. MEGGERS presiding)

Atomic Spectra and X-Rays

C1. Forbidden Lines in O II. L. H. ALLER, *University of Indiana,* C. W. UFFORD, *University of Pennsylvania,* AND J. H. VAN VLECK, *Harvard University.*—Among the strongest and most frequently observed of the forbidden lines found in the gaseous nebulae are the λ3726.16 and λ3728.91 lines of O II corresponding to the $^4S_{3/2}-{}^2D_{3/2}$ and $^4S_{3/2}-{}^2D_{5/2}$ transitions in the ground p^3 configuration. The widespread appearance of this radiation would suggest that a knowledge of the physical parameters characterizing its production (e.g. transition probabilities) might be useful in deciphering the character of the nebulous regions in which it appears in our own and other galaxies. If the electron density is so high that the collisional de-excitations of the upper level are much more frequent than radiative de-excitations, the population of the upper level follows Boltzmann's formula. Then measures of the intensity of the lines together with a knowledge of the electron temperature and the transition probabilities would give us the number of ionized oxygen atoms. For comparison with the theoretical calculations, including spin-spin interaction in addition to intermediate coupling, the ratio of the transition probabilities was measured photometrically in a number of planetary nebulae. The average measured value of the ratio was 0.49 as compared with a theoretical value of 0.58.

C2. The Zeeman Effect of Gold. J. B. GREEN, *Naval Ordnance Laboratory,* AND HOWARD N. MAXWELL, *Kalamazoo College.*—The Zeeman spectrum of gold has been photographed from 2400A to 6500A at a field strength of about 36,000 gauss. Patterns from some 28 classified lines for Au I were measured, about half of which were obtained with much better resolution than that of Symons and Daley. The calculated g values indicate that gold obeys an intermediate type of coupling rather than *LS.* The patterns for λλ5837, 4437, 4315 indicate these lines belong to Au I rather than Au II as given by Rao. Many of the Au II patterns were unresolved, but λ2990 has a pattern belonging to $\Delta J=0$. Sawyer and Platt have classified it as either $\Delta J=1$ or $\Delta J=0$. λ5726 classified as Au I by Sawyer and Platt has a well resolved pattern with $g=1.803$ for $J=1$ and 1.352 for $J=2$. term. The lines λλ5354, 5380, 5427 are members of the same multiplet and result from transitions between $J=2$, 1, 0 and the level $J=1$ whose g value is 1.780. λ5719 is a $J=2$ to $J=1$ transition with $g=1.744$ for $J=1$ term. The wave-lengths of a number of unclassified lines appearing on the plates have been measured on the assumption that the lines belong to gold.

C3. A Self-Consistent Field for Ca XIII. W. H. DAVIS, A. O. WILLIAMS, JR., AND R. T. BEYER, *Brown University.*

—Edlen has identified certain spectrum lines in the sun's corona as the result of transitions in highly stripped calcium ions.[1] A self-consistent field for one of these ions, Ca XIII, has been computed without exchange or relativistic corrections, with the intention of investigating these transitions. The calculations converge rapidly because of the large excess of nuclear charge. The degree of self-consistency attained is at least as good as that specified by Hartree. The state examined is $(1s)^2(2s)^2(2p)^4$; an "excited" state $(1s)^2(2s)(2p)^5$ has also worked out to the same precision. A first approximation to the transition energy between these two (*not* the corona line in question) is 510,000 cm^{-1}, to be compared with experimental values of 594,000 and 618,000 cm^{-1}. Since this value is only the difference between Hartree energy parameters, not between actual energy levels, it is naturally not very good. Calculations of the s.c.f. with exchange and of energy levels are in progress.

[1] Edlen, B. Month. Not. Roy. Astron. Soc. **105**, 323 (1945).

C4. Aurora Spectra Showing Broad Hydrogen Lines. C. W. GARTLEIN, *Cornell University.*—The best spectra of the aurora taken since 1939 with the two prism spectrograph having camera lens 10 cm focal length and *F*/1.65 aperture show lines within 2 to 5A of the positions of $H\alpha$, $H\beta$, and $H\gamma$. All of the lines are approximately 5A broad. Using large scale microphotometer tracings the lines can be separated from the various bands of nitrogen, and the identification as hydrogen lines seems established since no other origin will give these lines as the spectrograms show them. Many spectra taken on the time sequence spectrograph, aperture *F*/.8, show that these lines appear most strongly preceding and during an outburst of aurora. This is in support of Eckersley's theory of ionosphere disturbances. Thus, there is evidence to indicate that the hydrogen is of solar origin and a primary cause of some aurora outbursts and magnetic storms. Spectrographs of high light power and greater dispersion should be used in further studies.

* Research done as part of National Geographic Society—Cornell University Study of Aurora.

C5. A Prospective Means for Studying the Solar and Coronal Spectra in the Vacuum Ultraviolet. J. E. MACK, *University of Wisconsin.*—The great strides made recently in extending the known solar spectrum into the neighborhood of 50,000 cm^{-1} with the aid of rocket-borne spectrographs naturally lead to speculations on the possible extension of the solar and coronal spectra into the vacuum region. There can be little doubt that interesting structure exists there.[1] The only dispersive instrument that has been used for vacuum spectroscopy is the reflection grating; the focal property of the curved mirror is especially useful in gathering light from weak laboratory sources. The sun, with its great intensity, makes quite a different problem, especially in view of the serious incoherent scattering of visible light from the surface, which limits the usefulness of the solar record even at longer wave-lengths. A transmission grating, even with the disadvantages of requiring slit collimation instead of focusing, appears to be a promising alternative. Consideration has been given to the design and construction problem for a grating 1 mm square traversed by between 200 and 1000 wires.

[1] I. S. Shklovsky, Astronomical Journal of the Soviet Union **22**, 249 (1945).

C6. Low Angle Scattering of Colloidal Solutions. PETER G. BERGMANN, *Syracuse University.*—In analogy to the diffraction patterns of liquids, the low angle pattern of colloidally dispersed matter must depend on both particle size and particle distribution. The effect of the distribution will be appreciable whenever particle size and distance between neighbors are of the same order of magnitude, in other words in highly concentrated solutions. If the colloidal particles are all alike in size and shape, then the intensity of the diffraction pattern at each point will be the product of the form function of the particles and the Fourier transform of the particle distribution. An experimental determination of the latter function is then possible, at least in principle. The case of a size and shape distribution will also be discussed.

C7. The Interpretation of Small Angle X-Ray Scattering Observed from Argon. GEORGE H. VINEYARD, *University of Missouri.*—Measurements of the x-ray scattering from argon[1] at many different pressures and temperatures have shown an unexpectedly large scattering at small angles from both liquid and vapor in the neighborhood of the critical point. It has been suggested that this may be due to pre-transition phenomena such as the formation of minute droplets of liquid in the vapor, when near the condensation point, and the reverse for liquid near its boiling point.[1] By means of a relation due to Zernike and Prins between the scattering at very small angles and the mean square density fluctuations of a substance, the scattering at essentially zero angle can be computed. The small angle scattering to be expected from droplets of one phase immersed in another is also computed. From these results and the present data on argon an estimate of the size and frequency of occurrence of droplets is made, and it is found that the droplet would have to contain so few atoms that its characterization as a distinct phase is probably meaningless. Preferable models of the apparent atomic arrangement are discussed.

[1] A. Eisenstein and Gingrich, Phys. Rev. **62**, 261 (1942).

C8. Determination of h/e by X-Rays. GUENTER SCHWARZ AND J. A. BEARDEN, *Johns Hopkins University.*—New measurements have been made on the high frequency limit of the continuous x-ray spectrum near 8000 and 10,000 volts. In most of the work sealed-off x-ray tubes with Cu and W targets were used. Our present measurements are characterized by a highly stabilized source of high voltage and a double crystal spectrometer with crystals of theoretical resolving power. The resulting isochromats rise sharply and considerably more detail is present in the structure near the high frequency limit than was noted in our earlier measurements.[1] In one series of experiments a W target was maintained at a temperature

above 1300°C in order to eliminate possible effects due to surface contaminations. If we apply the work function correction the values of h/e determined from all of our experiments lie within the range from 1.3783 to 1.3787 $\times 10^{-17}$ erg sec./e.s.u. If the second derivative method had been used in determining the limit in our earlier measurements[1] the average value of h/e would have been 1.3786 $\times 10^{-17}$, is excellent agreement with our present determination.

[1] J. A. Bearden and G. Schwarz, Phys. Rev. 59, 934(A) (1941).

C9. Bioelectric Potentials as an Index of X-ray Action. A. A. BLESS, *University of Florida.*—Romanoff and Bless[1,2] have investigated the variation of the biolectric potential of the avian blastoderm and also the variation of the size of the blastoderm as a function of x-ray dosage, and have found that these variations follow the same pattern. A number of investigators have found a direct correlation between the magnitude of the potential and the vital activity of the organism. Recent results obtained in this laboratory show that the functional relations between the effects of x-rays on the vital activity of corn seeds and the effects of the same rays on the bioelectric potential are similar. It seems very reasonable to conclude that the biological effects of x-rays at least, if not of all types of radiation, may be traced through the variations of the electrical potentials of the material. This provides in many cases very rapid and reliable means of measuring the biological action of the rays without introducing new variables which is the case when the growth of organisms is used as a measure of biological effects.

[1] A. L. Romanoff and A. A. Bless, Proc. Nat. Acad. Sci., 8, 306 (1942).
[2] A. A. Bless and A. L. Romanoff, J. Cell. and Comp. Physiol., 21, 117 (1943).

THURSDAY MORNING AT 10:30

Hall of Government, Room 102

(E. M. PURCELL presiding)

Gases at Microwave Frequencies; Magnetic Resonance

D1. Electrical Breakdown between Coaxial Cylinders at Microwave Frequencies.* MELVIN A. HERLIN AND SANBORN C. BROWN, *Massachusetts Institute of Technology.*—The proposed criterion for breakdown of a low pressure gas at microwave frequencies is that the ionization rate equal the diffusion rate for electrons.† This principle has been applied to compute the breakdown of air in coaxial cylinders using ionization rate data obtained from breakdown experiments between parallel plates. Agreement between computed and measured curves supports the validity of the above criterion for breakdown. The method of computation is illustrative of the general problem of computing breakdown voltages for tubes of arbitrary shape and field configuration using ionization rates obtained from parallel plate, uniform field breakdown.

* This work has been supported in part by the Signal Corps, the Air Materiel Command, and O.N.R.
† Melvin A. Herlin and Sanborn C. Brown, Bull. Am. Phys. Soc. 23, 13 (1948).

D2. A Method of Measuring the Complex Conductivity of an Ionized Gas at Microwave Frequencies.* EDGAR EVERHART AND SANBORN C. BROWN, *Massachusetts Institute of Technology.*—The complex conductivity of an ionized gas, σ_e, is defined as the ratio of the electron current density to the electric field. It does not include the displacement conductivity, $j\omega\epsilon_0$. In order to measure σ_e, a high frequency discharge is created between parallel plates. By microwave impedance methods one can measure the admittance of the discharge. The admittance is expressible in terms of an integral over σ_e. According to existing theories σ_e is proportional to the electron concentration, which is itself a sinusoidal function of position between the parallel plates. It is possible to compute the admittance of a discharge as a function of electron concentration. These computed curves have the same qualitative form as those obtained experimentally. A characteristic of both theory and experiment is that the susceptance of the discharge goes through zero and changes sign at sufficiently high values of electron concentration.

* This work has been supported in part by the Signal Corps, the Air Materiel Command, and O.N.R.

D3. Measurements of the Complex Dielectric Constant of Gases at Microwaves. HAROLD LYONS, GEORGE BIRNBAUM, AND S. J. KRYDER, *National Bureau of Standards.*—A method for the measurement of the complex dielectric constant of gases and vapors has been developed in the microwave range. A frequency-modulated signal is simultaneously applied to two resonant cavities and their response curves presented on a cathode-ray tube. The cavities are adjusted to have the same resonance frequency, with one cavity evacuated. Gas is then admitted to the evacuated cavity causing its resonance frequency to shift. The difference in resonance frequency is measured by aligning two frequency markers, which appear as intensified spots on the CRT, on top of each resonance curve. The loss angle is measured by determining the cavity Q-shift by aligning the frequency markers at the half-power points of the resonance curve. Results obtained for $(\epsilon-1)\times 10^4$ at approximately 9000 Mc/sec. at NTP are: helium -0.710 ± 0.009, $CO_2-9.88\pm0.02$, $N_2-5.87\pm0.02$, $O_2-5.32\pm0.02$, Air -5.77 ± 0.01. Values for water vapor, and its dipole moment, were checked. The dielectric constant and loss angle of ammonia was found. The suscepti-

bility of ammonia was not linear with pressure as would be expected from collision broadening of the ammonia absorption line. The resonant cavity method, when the proper mode is used, is insensitive to adsorption of vapors on the walls of the cavity.

D4. A Comparison of the g Value of the Electron in Hydrogen and Deuterium. EDWARD B. NELSON AND JOHN E. NAFE, *Columbia University.*—The ratio of the h.f.s. separation of the ground state of H to that of D is less than the theoretical value by 0.017 percent. The ratio, $(g_J)_H/(g_J)_D$, of the atomic g-factor of the $^2S_{\frac{1}{2}}$ state in H to that of D, has been measured in the search for an effect which might explain the discrepancy. The frequencies f_H, of the transition $(1, 0\leftrightarrow 1, -1)$ in H, and f_D, of the transition $(3/2, -1/2\leftrightarrow 3/2, -3/2)$ in D, were observed in the same magnetic field by the atomic-beam magnetic resonance method and the ratio $(g_J)_H/(g_J)_D$ was computed from the Breit-Rabi[1] formula. The principal uncertainty is caused by the drift of the magnetic field. The average of thirty-six observations in four runs in which f_H and f_D were measured alternately is $(g_J)_H/(g_J)_D = 1.000004 \pm 0.000025$. The average of three runs in which the two resonances were observed simultaneously is $(g_J)_H/(g_J)_D = 0.999991 \pm 0.000010$. The uncertainty indicated in each result is the mean deviation of the residuals. We conclude that the atomic g-factors of H and D differ by less than ± 0.001 percent.

[1] G. Breit and I. I. Rabi, Phys. Rev. **38**, 2082 (1931).

D5. A Precision Magnetic Field Stabilizer.* H. S. SOMERS, JR., P. R. WEISS, AND W. HALPERN, *Rutgers University.*—The work at Rutgers University on measurements of nuclear magnetic moments by resonance absorption requires precision control of the field of a large electromagnet. A pilot model electronic current stabilizer for a ½-kw magnet has been built and tested. This unit monitors the current by the drop in a standard resistor in series with the magnet. The difference between this voltage and a preset potentiometer voltage is converted to a.c. in a Brown synchronous vibrator. The amplified difference signal is converted back to d.c. in a detector which maintains the sign of the original d.c. signal, and is used to drive the power amplifier which excites the magnet. The power amplifier is a low noise, broad-band unit with ½-kw output, made from a commercial mg set by addition of electronic feedback.** This unit keeps the current fluctuations to a ratio of less than 5×10^{-6} v peak to peak/v d.c. for all frequencies higher than 1/min. No measurements were made on the longer period drift. The loop requires ½-sec. to correct a step change of 0.02 percent and 2 sec. to correct a step of 1 percent.

* This work supported by O.N.R. and the Rutgers University Research Council.

** H. S. Somers, Jr., and P. R. Weiss, W. Halpern, Bul. Am. Phys. Soc. **23**, No. 2, Abstract E-1 (1948).

D6. Paramagnetic Resonance Absorption in Single Crystals of Chrome Alum and in Aqueous Solutions of Manganous Salts.* DAVID HALLIDAY AND JOHN WHEATLEY, *University of Pittsburgh.*—Paramagnetic resonance measurements at 9375 mc/sec. on single crystals of $CrNH_4(SO_4)_2\cdot 12H_2O$ have recently been reported by Weiss, Whitmer, Jen-Sen Hsiang, and Torrey[1] and interpreted by them to yield a splitting of the lowest level of Cr^{+++}, due to crystalline Stark effects, of 0.15 ± 0.01 cm^{-1}. We have made measurements on both this salt and $CrK(SO_4)_2\cdot 12H_2O$ for two crystalline orientations at room temperature. Resonance absorption for the latter salt has been studied at 90°K also. For the crystal orientation used by Weiss, etc. two independent values of the splitting may be determined for each salt; for the second crystal orientation a third splitting value may be determined, using a theory due to Kittel. The mean splittings are approximately:

$CrNH_4(SO_4)_2\cdot 12H_2O$	0.13 cm^{-1}	25°C
$CrK\ (SO_4)_2\cdot 12H_2O$	0.12 cm^{-1}	25°C
$CrK\ (SO_4)_2\cdot 12H_2O$	0.17 cm^{-1}	90°K

Paramagnetic resonance absorption has also been observed for aqueous solutions of manganous salts contained in a thin-walled capillary placed along the axis of a TE_{001} mode cavity[2] resonating at 9375 mc/sec.

* Assisted by ONR.

[1] P. R. Weiss, C. A. Whitmer, H. C. Torrey, and Jen-Sen Hsiang, Phys. Rev. **72**, 975 (1947).

[2] C. H. Collie, J. B. Hasted, and D. M. Ritson, Proc. Phys. Soc. **60**, 71 (1948).

D7. Paramagnetic Resonance Absorption Line Shapes for Single Crystals of $CuSO_4\cdot 5H_2O$.* JOHN WHEATLEY AND DAVID HALLIDAY, *University of Pittsburgh* AND J. H. VAN VLECK, *Harvard University.*—Paramagnetic resonance absorption in single crystals of $CuSO_4\cdot 5H_2O$ at frequencies near 9375 mc/sec. has been studied as a function of the steady external magnetic field and of the orientation of the crystal. As rotation axes (a) the magnetic axes of the crystal and (b) one of the two perpendicular microscopic tetragonal axes have been used. The high frequency field and the rotation axis were both perpendicular to the steady field. The variation with orientation of the effective g factor, reported by Arnold and Kip[1] and interpreted by one of us[2] in terms of exchange coupling between Cu^{++} ions, has been confirmed. A variation of absorption line breadth with orientation has been found, the narrowest and broadest lines having widths at half-amplitude of 75 and 220 oersteds. An approximate theory for this effect, based on the assumption that the exchange energy is a function only of the total spin, will be presented. Finally, a study of the shapes of absorption curves has been made which offers general confirmation of the theory of exchange narrowing recently presented by Gorter and Van Vleck.[3]

* Assisted by ONR.

[1] Arnold and Kip, Bull. Am. Phys. Soc. **23**, No. 2, F5 (1948).

[2] J. H. Van Vleck, Bull. Amer. Phys. Soc. **23**, No. 2, G8 (1948).

[3] C. J. Gorter and J. H. Van Vleck, Phys. Rev. **72**, 1129 (1947).

D8. Microwave Resonance Absorption in Potassium Chrome Alum.* R. T. WEIDNER, P. R. WEISS, AND C. A. WHITMER, *Rutgers University.*—The paramagnetic resonance absorption in single crystals of potassium chrome alum has been measured at a frequency of 9375 mc/sec. The measurements were made with three different orientations of the crystalline axes with respect to the d.c. magnetic field. These orientations were: the d.c. field perpen-

dicular to (*a*) the 111-face, (*b*) the 100-face, (*c*) the 110-face. Crystals of this salt diluted with aluminum potassium alum were also measured in these same orientations. The absorption patterns show that dilution decreases the Stark splitting of the ground state of the chrome ion. In addition, there is a marked decrease in the absorption peaks of the diluted salt compared to those of the undiluted salt.

* This work has been supported by the Rutgers Research Council, the Research Corporation, and the U. S. Navy.

D9. Microwave Resonance Absorption in Ferromagnetic Semiconductors. WILLIAM H. HEWITT, JR., *Bell Telephone Laboratories.*—The high resistivity of ferrites suggests that measurements of ferromagnetic resonance absorption may be of particular interest. The absorption effect is expected to be large in comparison with that in conducting ferromagnetic materials, because the greater skin depth permits a relatively larger volume of the specimen to absorb. Measurements were made at 23958 megacycles with a thin plane specimen of zinc-manganese ferrite (ZnO) (MnO)·$2Fe_2O_3$ fitted across the wave guide. It has a resistivity of 2350 ohm-cm, initial permeability of 1700 at 1000 cycles, and saturation magnetization M_s of 200. The input impedance looking into the specimen was determined as a function of the applied magnetic field when the sample was backed first by a short and then by a quarter wave-length section. With this data, the real and imaginary parts of both the permeability and the dielectric constant were separated. Using[1] $\omega_0=\gamma(BH)^{\frac{1}{2}}$ where $\gamma=ge/2mc$ and H(corrected for demagnetization) is the field strength when $j\mu_2$ is maximum we find a g value of 2.12. With a small sphere of a similar ferrite with a higher resistivity (4.2×10^4 ohm-cm) a g value of 2.16 is obtained using $\omega_0=\gamma H$.

[1] C. Kittel, Phys. Rev. 73, 155 (1948).

D10. The Electric Quadrupole Moments of the Chlorine Nuclei.* LUTHER DAVIS, JR. AND CARROLL W. ZABEL, *Massachusetts Institute of Technology.*—The hyperfine structures of the $^2P_{3/2}$ ground state of Cl^{35} and Cl^{37} have been determined by the atomic-beam magnetic resonance method. For both isotopes, $I=J=3/2$, there are four energy levels at zero magnetic field, corresponding to $F=0$, 1, 2, and 3, given by the relation $W=a(C/2)+(b'/24)C(C+1)+c[C^3+4C^2+4(C/5)]$ where $C=F(F+1)-I(I+1)-J(J+1)$, a is the magnetic dipole, b' the electric quadrupole, and c the magnetic octupole interaction constant. The measurement of the separations between adjacent levels, $a-b'+153.1c$, $2a-b'+54.2c$, $3a+b'+171.3c$, allows the determination of the interaction constants a, b', and c.

$a_{35}=205.288\pm0.030$ Mc, $a_{37}=170.686\pm0.030$ Mc,
$b'_{35}=55.347\pm0.070$ Mc, $b'_{37}=43.256\pm0.070$ Mc,
$c_{35}=380\pm500$ c.p.s. $c_{37}=20\pm500$ c.p.s.

After including small relativity corrections the electric quadrupole moments calculated from the ratio b'/a are $Q_{35}=-(7.921\pm0.05)\times10^{-26}$ cm², and $Q_{37}=-(6.189\pm0.05)\times10^{-26}$ cm². An unusual method was used to observe the $F=1$ to $F=0$ transition. The refocused beam intensity, due to transitions between $F=1$ and $F=2$, was diminished by superimposing a second oscillating field corresponding to the transition from $F=1$ to $F=0$.

* This work has been supported in part by the Signal Corps, the Air Materiel Command, and O.N.R.

D11. A Recording Microwave Refractometer. GEORGE BIRNBAUM, *National Bureau of Standards* (*Introduced by Harold Lyons*).—This instrument can measure and continuously record the dielectric constant (or index of refraction) of low loss gases, liquids, and solids. A sawtooth frequency-modulated signal is simultaneously applied to two cavity resonators, one used as a reference cavity, the other to contain the dielectric sample. The output of the cavity resonators yield resonance responses which are amplified in separate channels. These resonance responses are sharpened and applied to a trigger tube which is turned on by one pulse and turned off by the other. The average output current of the trigger tube is metered. For a linearly frequency-modulated output from the microwave oscillator, the trigger-tube output current is proportional to the frequency difference between the two cavities. It appears possible with some refinements to detect a very small change in frequency of 1 part in 10^8. The output of the circuit is made to drive a recording meter and is thus capable of following rapid changes in index of refraction. Modifications are possible which will allow recording of the absorption coefficient or loss angle of dielectrics. The instrument should lend itself to microwave propagation measurements.

THURSDAY MORNING AT 10:30

National Academy of Sciences

(D. R. INGLIS presiding)

Theoretical Physics

E1. A Special Property of the Electron's Gyromagnetic Ratio. JOSEPH W. WEINBERG, *University of Minnesota.*—Theoretical cross sections for electromagnetic processes at high energies for charged particles of spin $h/4\pi$ and magnetic moment $g(eh/4\pi mc)$ are largely proportional to powers of $(g-1)^2E^2$,[1] and are markedly reduced when, as for the electron, $g=1$. This is explained by the classical picture of a charge e, of magnetic moment M, which, in a

rest system, ($v=0$, $c=1$), obeys $dv/dt=(e/m)E$, $dM/dt=g(e/m)M\times H$. Relativity requires the existence of an electric moment $P=M\times v$, which vanishes in a rest system, but has a finite rate independent of g. Acceleration of the moments produces magnetic and electric dipole radiation, whose destructive interference cancels the dominant contribution when $g=1$. This accounts for those features of the quantum cross sections properly ascribed to radiation. Additional g-sensitivity due to the deflection process can be inferred from the quantum picture of momentum transfer as mediated by photons. The classical spectrum has been investigated for the case of impact radiation in a Coulomb field, where the moments are submitted to sudden changes $\delta P=M\times\delta v$, $\delta M=gM\times[\delta v\times v]$. Modified and reinterpreted by the correspondence principle, the result agrees quantitatively with the field-theory cross section for radiation after deflection through $\delta v/v$, divided by the corresponding elastic scattering cross section.

[1] W. Pauli, Jr., Rev. Mod. Phys. **13**, 203 (1941).

E2. An Invariant Quantum Electrodynamics. JULIAN SCHWINGER, *Harvard University.*—In order to isolate the divergent aspects of current quantum electrodynamics[1] in a manner that is Lorentz- and gauge-invariant, it is necessary to employ a formulation of the theory that preserves these invariant features at all stages. This has been achieved by a field theory generalization of Dirac's many-time formalism for particles interacting with the electromagnetic field, in which infinitesimal spatial volume elements play the role of particles. An appropriate canonical transformation enables one to exhibit the self-energy modifications of electron and photon properties, which, for the electron, correspond to the addition of an invariant, though divergent, electromagnetic mass. Self-energy effects for the photon vanish identically, in contrast with previous theories. The radiative corrections to the interaction energy of an electron with an external field are obtained in properly covariant form. In particular, we confirm the additional spin magnetic moment, $\delta\mu/\mu=(1/2\pi)(e^2/\hbar c)$, obtained previously from a non-invariant formulation.

[1] J. Schwinger, Phys. Rev. **73**, 415 (1948).

E3. Variational Principles for Diffraction Problems. HAROLD LEVINE AND JULIAN SCHWINGER, *Harvard University.*—The diffraction of a scalar plane wave by an aperture in a plane screen is described in terms of two variational principles. An important role is assumed by the amplitude of the diffracted spherical wave at large distances from the aperture. For a boundary condition which requires that the wave function vanish on the screen, explicit expressions for the amplitude are obtained, which have the property of being stationary with respect to variations relative to the correct values of (1) the wave functions in the aperture, and (2) the discontinuities in the normal derivative of the wave functions at the screen, arising from a pair of incident waves. In addition, these expressions are independent of the scale of the wave functions. From the detailed application to a problem for which exact results are available,[1] it appears that when combined with suitable trial functions, the variational principles provide approximate, yet accurate expressions over a wide range of frequencies for the diffracted amplitude and transmission cross section. The formulation is extended to the diffraction of an electromagnetic plane wave, with the assumption of a perfectly conducing screen.

[1] C. J. Bouwkamp, "Theoretical and numerical calculation of diffraction by a circular aperture," Dissertation (In Dutch), Groningen, 1941.

E4. A Relativistic Cut-Off for Quantum electrodynamics. R. P. FEYNMAN, *Cornell University.*—According to Lienard and Wiechert, the classical electromagnetic potentials at one point depend on the charges and currents at another point at a distance r at a time earlier by $t=r/c$. The influence is proportional to the retarded part of the Dirac delta-function of the square of the four-dimensional interval $S^2=t^2-r^2/c^2$. We replace this delta-function by a finite arbitrary function of S^2 of very small width a^2. When the corresponding alteration is made in quantum mechanics, quantities which previously were infinite turn out finite. The self-energy of a free electron behaves as a change in mass. The change depends logarithmically on a. The electromagnetic correction to a scattering cross section and the self-energy of a bound electron also depend logarithmically on a. When expressed, however, in terms of the corrected mass of the free electron, these quantities are not sensitive to a and remain finite as a approaches zero. They then agree with the results of Bethe, Weisskopf, Lewis, and the theory of Schwinger,* except for terms corresponding to polarization of the vacuum. These terms are not made convergent by the above procedure. The procedure is relativistically invariant.

* See, for example, Bull. Am. Phys. Soc. **23**, No. 2, Z-8, Z-9, Z-10 (1948); also H. W. Lewis, Phys. Rev. **73**, 173 (1948).

E5. Boundary Conditions as Relativistic Interaction. MARCOS MOSHINSKY AND E. P. WIGNER.—The simplest type of relativistic interaction between two particles, which necessarily leads to convergent results, can best be formulated in an eight-dimensional configuration space-time. Both time derivatives of the wave function are given by the corresponding free particle equation at all points in configuration space, and it is postulated that the wave function be regular everywhere except at the points where the space-time coordinates of the particles coincide. At these points, the wave function can have a singularity. It then turns out that the relativistic invariance and the conservation law of probability determine the singularity up to a constant: For two Klein-Gordon particles this singularity gives rise to a scattering cross section $4\pi a^2/(1+k^2a^2)$; where a is the constant in question and k the wave number of the relative motion of the two particles. Other types of interaction can be formulated in Fock space, the simplest ones being the disintegration of one particle into two (and the reverse process), and the transformation of two particles into two particles of different masses, etc. In this last case the difference of the squares of the two masses must be the same before and

after collision. The apparent impossibility of incorporating the ideas of the "hole theory" into low dimensional configuration spaces makes it unlikely that these considerations will enable one to avoid introducing functionals.

E6. On the Integral Equations of Motion. ELLIOT T. BENEDIKT, *North American Aviation.*—The equations of motion for a particle and for a general mechanical system will be set up in integral form. A solution of the above equations by an iteration process will be discussed for the case of a particle moving under the combined action of a time-dependent and a position-dependent conservative force. The above procedures will be applied to the case of a particle moving in a central Newtonian field, under the action of a (finite) time-dependent force.

E7. Statistical Error in Transmission Measurements. M. E. ROSE AND M. M. SHAPIRO, *Clinton National Laboratory.*—In certain exponential absorption experiments it is important to achieve minimum statistical error in a limited time or to minimize the counting time required to measure the absorption coefficient with a preassigned accuracy. The conditions required to attain these ends, i.e., the geometry for optimum transmission and the optimum apportionment of counting times along the incident and transmitted beams and background, have been investigated for a wide range of relative backgrounds (10^{-3} to 10^{3}) and for two geometries: (1) beam area fixed, absorber thickness alone is varied; (2) beam area and absorber thickness are both disposable parameters, while the total amount of absorber intercepting the beam remains fixed. In both cases the flux density and background rate are assumed constant. The optimum transmissions are shown to be, in general, considerably small than those commonly used in absorption experiments. Thus, for case (1), a useful rule is to employ a transmission of about 0.1 for low backgrounds, 0.2 for moderate backgrounds, and 0.3 for high backgrounds. The following have also been determined: (*a*) minimum statistical error for a given total counting time; (*b*) statistical error and the best distribution of counting times for non-optimum geometry; (*c*) sensitivity of the accuracy or total counting time to deviations from optimum transmission.

E8. Symmetry Properties of Ψ-functions. G. J. YEVICK, *Stevens Institute of Technology.*—The Young symmetry operator[1] proves to be a simple but powerful tool in the analysis of the *n*-body problem in quantum mechanics. For Ψ-functions with symmetries other than completely symmetric (Einstein-Bose statistics) or completely antisymmetric (Fermi-Dirac statistics), Wigner has suggested that it may be possible to construct the interaction between a collection of non-mutually interacting particles and the particles which create or destroy them, in such a manner that the first collection is automatically forced into the desired symmetry. It appears that this can be done with the aid of the Young symmetry operator. The full consequences of such a procedure have not yet been worked out. In order to apply such a method—especially for the involved problem of second quantization—a complete analysis of the symmetry properties of the Ψ-functions for a fixed number of particles has been carried out. In addition to the Young symmetry operator, the Laplace identity relations for determinants provide the general solution to such an analysis.

[1] See E. G. Weyl, *Group Theory and Quantum Mechanics*, Chapter V.

E9. Irreversibility and Quantum Mechanics.* L. TISZA, *Massachusetts Institute of Technology.*—The formalism of quantum mechanics is symmetric with respect to future and past, whereas in thermodynamics the increase in entropy marks an asymmetry. The numerous attempts at reconciling the two points of view seem not quite satisfactory. Some progress has been achieved on the following lines: the increase in entropy is a consequence of the destruction of phase relations connected with the limitations of the observer dealing with molecular systems. These limitations are in addition to those inherent in quantum mechanics and can be expressed as follows: (1) Only such macroscopic operations and measurements are feasible which may be expressed in the Hilbert space of a single particle and which affect all similar particles identically. (2) The *principle of thermal uncertainty* states that a completely closed system is an inadmissible idealization, since the system must interact at least with the walls and other devices by which it is shielded from the surroundings. The resulting "thermal noise" is essential for the increase in entropy, which would be impossible if the temporal behavior of the system were determined by a rigorously constant Hamiltonian operator. The situation is analogous to that in communication where the information contained in the signal is decreased only because of noise.

* This work has been supported in part by the Signal Corps, The Air Materiel Command, and the O.N.R.

E10. Note on the General Properties of *S* Matrices. T. S. CHANG, *Carnegie Institute of Technology (Introduced by F. Seitz).*—The general properties of S matrices are reexamined. First, we show that the equation $S\dagger S=1$ expressing the unitariness of the S matrix is not true in general, and must be modified by the introduction of a non-positive-definite weight w. This corresponds to the fact that there are negative probability densities in the relativistic theory of elementary particles. Next, S is determined in terms of wave matrices, Ψ representing outgoing and incoming scattered waves (plus incident waves), and the commutability between S and the Hamiltonian (if any) is discussed. Next, a difficulty connected with the description of the discrete states by the wave matrices at $S=0$ and at pure imaginary values of the magnitude of the momentum is pointed out. Finally, with S assumed to transform in a Lorentz transformation as Ψ should, the wave matrices Ψ in the S matrix theory are shown to transform only approximately correctly in the x representation (i.e., they transform correctly only after the neglect of terms $0(\gamma^{-2})$, γ being the distance between the scatterer and the scattered particle).

THURSDAY AFTERNOON AT 2:15

Lisner Auditorium

(J. R. OPPENHEIMER presiding)

Invited Paper

EA1. Why My Stork Chose 1868. R. A. MILLIKAN, *California Institute of Technology.* (45 min.)

Contributed Papers on Cosmic Rays

EA2. Directional Distribution of the Total Cosmic Radiation at Atmospheric Heights up to 10-cm Hg at Princeton.* JOHN WINCKLER, *Princeton University.*—The intensity distribution of cosmic-ray particles as a function of zenith and azimuth was measured by unshielded Geiger counters carried by balloons. Four threefold telescopes directed in the vertical, horizontal, and at 30° and 60° zenith angles, were used. Additional counters registered air showers. Pressure, temperature, orientation, and cosmic-ray events were transmitted to a ground recording station by a 15-channel radio telemetering system.

A preliminary analysis of the data indicates the following facts:

(a) The sea level $\cos^2\theta$ dependence angle θ is modified near 10-cm Hg to a more isotropic distribution, in which the horizontal intensity is 20 percent of the vertical and the intensity at $\theta=60°$ is 50 percent (showers excluded).
(b) Within the statistical accuracy of the data there is no azimuthal effect at any zenith angle.
(c) Total air showers are 10 percent of the vertical intensity. Showers accompany in equal numbers coincidences at $\theta=0$, 30°, and 60°, and in smaller numbers at $\theta=90°$.
(d) The vertical intensity-altitude curve agrees with the results of Pfatzer.

It is planned to continue the experiments at higher altitudes (≈1-cm Hg) using lead filters and more efficient shower protection.

* This work was performed under contract with the Office of Naval Research.

EA3. East-West Asymmetry, Zenith Angle Dependence, and Flux Measurements of Cosmic Rays up to 36,000 Feet.* JAMES F. JENKINS, JR., *Johns Hopkins University.*—The counting rates of counter telescopes with 0, 2, 8, and 10 cm of Pb were measured in B-29 aircraft at Inyokern, California (43° N geomagnetic latitude) from 2250 to 36,000 feet. For the hard telescopes (8- and 10-cm Pb) the data were taken at 0° and 45° off the vertical and at north, east, south, and west geographical directions in the 45° position. For the soft telescopes (0- and 2-cm Pb) the data were taken only in the vertical position. The counting rates of two pairs of G-M tubes were also measured at these altitudes—one pair under 2-cm Pb and the other under no Pb. Asymmetries of west over east in the order of 10 percent were observed at altitudes greater than 20,000 feet for penetrating particles. In this same altitude range, showers showed a west to east asymmetry of from 3 percent to 18 percent. From a consideration of the two points, (0° and 45°) at each altitude, on the zenith angle curve, it is seen that if a $\cos^n\theta$ relationship is assumed, that $n=2$ up to 18,000 feet, and then falls off toward $n=0$, the value at 36,000 feet being $n\sim1$. This is in accordance with the findings of Swann.[1]

* This work has been made possible by the support of the Navy Bureau of Ordnance.
[1] W. F. G. Swann, Rev. Mod. Phys. 11, 242 (1939).

EA4. Density Spectrum and Latitude Dependence of Extensive Air Showers at Sea Level.* S. F. SINGER, *Johns Hopkins University.*—An arrangement of four closely spaced trays, each containing ten Geiger counters, was used to investigate the particle density spectrum of extensive air showers (Auger showers). The measurements were carried out in Silver Spring, Maryland (geomagnetic latitude 50°), and in the Canadian Arctic ($\lambda=80°$ to 90°). In both cases the material above the counters was 0.6 g/cm² of wood. Master coincidences were formed between the *parallel* outputs of three counter trays (*A*, *B*, and *C*) and subsidiary coincidences between the master coincidence pulse and the *individual* Geiger counters in two trays (*A* and *D*). This served to speed up the process of data taking and also gives information about the structure of showers. No latitude dependence was found over the range of densities which could be resolved by the apparatus. The method of computation of a power law spectrum for particle densities, also correlations with a shielded ion chamber, and the theoretical implications of the results will be discussed.

* This work has been made possible by the support of the Navy Bureau of Ordnance.

EA5. Neutron Densities in the Atmosphere as a Function of Latitude and Altitude.* J. M. SIMPSON, JR., *University of Chicago.*—The densities of neutrons with energies greater than 0.3 ev were measured in aircraft using boron trifluoride proportional counters. It may be shown that these measurements correspond to free space measurements. The total vertical intensity of charged particles traversing 5 g/cm² and the vertical intensity of mesons traversing 20 cm of lead were also measured at the same time. The factor of increase of neutron density between 0°

and 53° N magnetic latitude is much greater than the corresponding latitude factors for the total vertical intensity or for the so-called "soft" vertical intensity. At 45-cm Hg pressure the factor for neutrons is 2.3±0.1; at 30-cm Hg it is 2.8±0.1; at 20.0-cm Hg it is 3.3±0.2; and at 15.0-cm Hg it is 3.5±0.2. The total exponential absorption of the neutron producing radiations corresponds to: 192±8 g/cm² at 0° and 19° N; 181±7 g/cm² at 40° N; 160±7 g/cm² at 53° N. All measurements were made between pressure altitudes of 10^4 and 3.7×10^4 feet. Some measurements of neutron production in aluminum and lead have been made. The results and interpretation of the above data will be discussed.

* A portion of this work was supported by the Office of Naval Research.

EA6. A Possible Circulation of Cosmic-Ray Helium Particles Around the Earth.* W. F. G. SWANN, *Bartol Research Foundation.*—Chandrashekhar Aiya found a sudden drop in cosmic-ray intensity at 21 cm of lead thickness at an altitude of 3110 feet on the magnetic equator. W. F. G. Swann and P. A. Morris found a similar drop at 22 cm of lead at Bocayuva at an altitude of 2300 feet near the magnetic equator, but found no such drop at Swarthmore, Pennsylvania.

A drop of the kind cited indicates a sharp peak in the spectral energy distribution curve at the top of the atmosphere, the peak occurring at an energy necessary for mesotrons to penetrate to the point of observation and through the thickness of lead concerned. Such a peak invites the assumption of heavy nuclear particles circumscribing the earth at the magnetic equator and breaking up into mesotrons. It is shown that a single ionized helium primary with energy such as to enable it to circulate around and near the earth at the equator would, on breaking up into 40 mesotrons, endow each mesotron with an energy of 1.2×10^9 ev. The mesotron energy necessary to penetrate at Bocayuva and through the 20 cm of lead is 1.3×10^9 ev.

* Assisted by the Office of Naval Research and by the National Geographic Society.

EA7. Rocket Borne Cloud Chamber I. S. E. GOLIAN, C. Y. JOHNSON, AND M. KUDER, *Naval Research Laboratory.*—A cloud chamber of 6-inch diameter was sent aloft in a V-2 rocket launched on January 22. The chamber contained argon at 2-atmospheres pressure and 2 lead plates of 1-cm thickness. Expansions were made every 25 seconds without counter control. Twelve photographs were taken at high altitude. A description of the apparatus and of some of the photographs will be given.

EA8. Rocket Borne Cloud Chamber II. G. J. PERLOW, E. KRAUSE, AND C. SCHROEDER, *Naval Research Laboratory.*—Additional analysis of the photographs of the previous abstract will be given. Particular emphasis will be placed on the results of counter experiments made in other rocket flights.

THURSDAY AFTERNOON AT 2:15

Hall of Government, Room 102

(E. M. McMILLAN presiding)

Neutrons

F1. Diffusion of Neutrons without Change in Energy in a Medium with an Isotropic Scattering. M. A. GREENFIELD, *North American Aviation.*—Using Mark's[1] method of solving the transport equation for diffusing neutrons with anisotropic scattering, the writer has considered the case for a semi-infinite absorbing medium containing sources. It is shown that the neutron density has a spatial dependence as $e^{K_0 z}$ where K_0, reciprocal of the diffusion length, is given by:

$$\frac{1}{2l_s K_0}\ln\frac{1+K_0 l}{1-K_0 l}=\frac{1+(3b/l_s l_c K_0^2)}{1+(3b/l l_c K_0^2)},$$

l, l_s, l_c, b are, respectively, the total, scattering, capture mean free paths and the average cosine of the scattering angle. If b is 0, the expression reduces to one given by Placzek.[2] In the case treated by Mark, the neutron density gradient is essentially constant a few mean free paths from the boundary; a constant gradient suffices to supply neutrons leaking out at the boundary. For an absorbing medium the density gradient increases away from the boundary to supply the absorption load as well as the leakage neutrons.

[1] J. C. Mark, "Milne's problem for anisotropic scattering," Nat. Research Council of Canada, 1947.
[2] G. Placzek and G. M. Volkoff, "Notes on diffusion of neutrons without change in energy," Nat. Research Council of Canada, 1943.

F2. Neutron Diffusion in Shielding Materials.* P. C. GUGELOT AND M. G. WHITE, *Princeton University.*—Neutron absorption experiments have been carried out to obtain information on the shielding qualities of different concrete blocks of 46×46×46 cm. A steel tube of 7.5-cm diameter through the center of the block and parallel to the neutron beam could be filled with concrete slabs of 5.3-cm thickness. Silver foils with or without Cd absorbers were placed between the slabs and activated by neutrons from 18-Mev protons on Be. A G.M. counter placed between the slabs gave information on the ionizing radiation inside the block. The following mixtures have been investigated. The half-value thickness (D_{A_g} in cm) at $d=20$ cm for the 2.3-min Ag activity excited by thermal

neutrons and the half-thickness (D_C in cm) for the counter at $d=20$ cm were:

Mixture	gr H_2O/cm³	gr Fe/cm³	Density	D_{Ag}	D_C
Concrete	0.20	—	2.35	9.5	13.3
Concrete+1.2% Pyrex	0.14	—	2.39	8.5	13.3
Cement+limonite ore	0.49	0.93	2.63	4.8	9.0
Cement+limonite+Fe	0.35	3.23	4.41	4.5	7.9
Cement+limonite+Fe +1% Pyrex	0.45	2.26	3.60	4.9	7.7
Cement+magnetite	0.21	1.93	3.78	8.2	9.0
Water	1.00	—	1.00	6.0	14.8

* Supported in part by Navy contract.

F3. Depolarization of Neutrons during Diffusion. S. BOROWITZ, *New York University.*—Following a recent suggestion[1] we consider the cumulative effect of several depolarizing collisions as a possible method for investigating the spin dependence of nuclear forces, when the scattering amplitudes are almost equal. Specifically, we examine the following situation: a plane monochromatic beam of polarized, thermal neutrons is incident normally on a semi-infinite slab of material of finite thickness, which scatters the neutrons isotropically and elastically. We wish to calculate the polarization of the transmitted beam. The transport equations for the neutrons of each polarization lead to a coupled system of integro-differential equations which reduce to a pair of equations of the Wiener-Hopf type. The equations are solved approximately by a method originated by G. C. Wick.[2] The first approximation is equivalent to considering the process a diffusion; the higher approximations, which converge rapidly, correct for the non-spherical distribution of the neutron density. The results indicate that conditions for performing an experiment are favorable. For a thickness of scatterer of 10 mean free paths, one obtains considerable depolarization for reasonable values of the scattering amplitudes. Using a pile as a neutron source, the intensity is not reduced beyond what is easily measured.

[1] M. Hamermesh and J. Schwinger, Phys. Rev. **71**, 678 (1947).
[2] G. C. Wick, Zeits. f. Physik **121**, 702 (1943).

F4. Inelastic Scattering of Fast Neutrons. L. SZILARD, S. BERNSTEIN, B. FELD, AND J. ASHKIN, *University of Chicago.*—Measurements of inelastic scattering effects of Ra$-\alpha-$Be and Ra$-\alpha-$B neutrons in Fe, Pb, and Bi have been made. A U^{238} fission threshold detector was used. The method consisted in measuring the fission counting rate in the detector with and without the spherical scatterer surrounding the source. From the decrease in the counting rate caused by the presence of the scatterer, values of the cross section for inelastic scattering to below the U^{238} fission threshold were calculated for several assumed values of the elastic scattering cross section. For example, if the elastic scattering cross section is taken equal to zero, the inelastic scattering cross sections in barns are as follows:

	Ra$-\alpha-$Be neutrons	Ra$-\alpha-$B neutrons
Fe	1.0	0.8
Pb	1.2	0.9
Bi	1.5	1.1

F5. The Recently Improved Slow Neutron Velocity Spectrometer with Some of the Results Obtained. W. W. HAVENS, JR., L. J. RAINWATER, C. S. WU, AND J. R. DUNNING, *Columbia University.*—The Columbia University slow neutron velocity spectrometer system[1] has been improved by using a 1-mc crystal oscillator to provide the fundamental timing. This permits cyclotron and detector "on times" of 2, 4, 8, 16, etc. microseconds. Total cycle periods of 1024 or 8192 μsec. are used, depending on whether or not Cd filters can be used. Using 2 μsec. "on-times" and a 6-meter path length gives a total effective resolution width <1 μsec./meter. Since a time of flight of 0.72 μsec./meter corresponds to a neutron energy of 10,000 ev, it is now possible to observe strong neutron resonance levels above 1000 ev as sharp deep dips on a curve of slow neutron transmission *vs.* time of flight. Results will be shown for Al, Zn, Cr, and NaBr, showing strong neutron resonance levels above 1000 ev. This document is based on work performed for the Atomic Energy Commission.

[1] J. Rainwater and W. W. Havens, Jr., Phys. Rev. **70**, 136 and 154 (1946); Rainwater, Havens, Wu, and Dunning, *ibid.* **71**, 65 (1947); Havens, Wu, Rainwater, and Meaker, *ibid.* **71**, 165 (1947); Wu, Rainwater, and Havens, *ibid.* **71**, 174 (1947).

F6. Neutron Scattering Resonances in Elements from Scandium to Arsenic. S. P. HARRIS AND A. S. LANGSDORF, JR., *Argonne National Laboratory.*—Since the discovery of the predominantly scattering character of the resonance in Mn for 300-ev neutrons, a search for similar resonances has been made using an annular BF_3 proportional counter as described in a published report on the scattering character of the 115-ev Co resonance. This apparatus permits observation of resonance scattering up to a few thousand ev. We have observed similar resonance scattering effects in Cu, Ga, and indications of such resonances in Sc, V, and As. The latter three are difficult to measure because the presumed resonances are above 1000 ev where the sensitivity of detection is low. The resonance in Cu is probably in the region of 500 to 1000 ev. In the case of Ga, both isotopes seem to have such resonances, and both in the range 100 to 500 ev. All the above are odd atomic number elements. Among even atomic number elements resonance scattering effects are consistently weaker, being practically unobservable in Fe and Ni, and small but observable in Ti and Cr. In Zn the resonance effect seems clear-cut. It is possible that the observed resonance scattering effects in these even atomic number elements are ascribable to the odd mass number isotopes of low abundance. Since none of these can be activated, enriched isotopes will have to be used to confirm this supposition.

F7. Total Neutron Cross Sections of Compounds with Different Crystalline Structures. LESTER WINSBERG, DAVID MENEGHETTI, AND S. S. SIDHU,* *Argonne National Laboratory.*—The total neutron cross sections of polycrystalline compounds such as close-packed hexagonal ZnO, body-centered cubic TlBr, and face-centered cubic CaO were determined with the Argonne neutron velocity selector[1] and neutron crystal spectrometer[2] in the energy region of 0.001 to 1.0 electron volts. The curves of cross

section as a function of neutron energy were resolved as a sum of absorption, coherent scattering, and incoherent scattering cross sections. These curves contain cross-section peaks, which are due to coherent scattering from various crystalline planes. The positions of the peaks come at neutron wave-lengths which satisfy the relation, $n\lambda = 2d$, where n is the order of the reflection and d is the interplanar distance. These diffraction effects are similar to those obtained with x-rays. The cross sections calculated by means of Eqs. (4) and (6) in reference 3 were compared with the experimentally obtained curves.[3] The change in the phase of the neutron wave on scattering by Zn and Ca is the same as that for O, which is in agreement with the work of Fermi and Marshall, and for Tl is the same as for Br. The free-atom scattering cross section of Ca determined from these data is 2.5 ± 0.5 barns, based on a value of 4.1 barns for 0. The corresponding scattering amplitude for Ca is $0.46 \pm 0.05 \times 10^{-12}$ cm. These values for Ca are much less than any previously reported.

* On leave from the University of Pittsburgh.
[1] T. Brill and H. V. Lichtenberger, Phys. Rev. **72**, 585 (1947).
[2] W. H. Zinn, Phys. Rev. **71**, 752 (1947).
[3] E. Fermi, W. J. Sturm, and R. G. Sachs, Phys. Rev. **71**, 589 (1947).

F8. Oscillatory Method for Measuring Neutron Cross Sections by the Effect on the Reactivity of a Chain-Reacting Pile. ALEXANDER LANGSDORF, JR., *Argonne National Laboratory.*—An increase in sensitivity by a factor of about 20 over the already described static control rod method[1] has been achieved by oscillating samples in and out by the Argonne heavy water pile (at one cycle per 20 seconds). The a.c. ripple in ion current from a BF_3 chamber in the pile is measured by a galvanometer circuit. Emphasis has been placed upon measuring resonance absorption, $\int \sigma_a dE/E$, of samples oscillating in a cadmium tube. One then measures capture, slowing down and scattering effects. The scattering may almost be eliminated, slowing down calculated, and $\int \sigma_a dE/E$ determined except for some light elements. Total pile cross sections are measured by removing the Cd sleeve. Then absorption as small as by Bi ($\sim 0.05 \times 10^{-24}$ cm^2 including impurities) may be measured to a few percent in spite of 200 times greater σ_s, using a 1000-g sample.

[1] H. L. Anderson, E. Fermi, A. Wattenberg, G. L. Weil, and W. H. Zinn, Phys. Rev. **72**, 16 (1947).

F9. Delayed Emission of Neutrons from the Decay of N^{17}. N. KNABLE, E. O. LAWRENCE, C. E. LEITH, B. J. MOYER, AND R. L. THORNTON, *University of California, Berkeley.*—The bombardment of oxygen and elements immediately above it in atomic number with 195-Mev deuterons is observed to yield a delayed emission of neutrons decaying with a half-life of slightly over four seconds. Measurements of the decay periods, with a BF_3 proportional counter corrected for resolving time, for target elements from oxygen through chlorine gave a single half-life of 4.14 ± 0.04 seconds. Observations of the intensity of gamma-radiation, together with the magnitude of the yield of delayed neutrons, precluded an explanation in terms of $\gamma - n$ reactions. Bombardments of various elements by deuterons, protons, and neutrons indicated that the active isotope responsible for the decay period leading to the neutron emitter must have $Z \leq 8$ and $A - Z = 10$. Subsequent experiments by Alvarez[1] definitely assigned the effect to a nitrogen isotope, identifying N^{17} as the nucleus which carries the phenomenon. Results of a general search through the periodic table for such effects will be reported. Complex decay curves for delayed neutrons from Ce, Gd, Pt, Au, Hg, Tl, Pb, and Bi will be shown. This work was performed under the auspices of the Atomic Energy Commission.

[1] See abstract F11.

F10. Production of N^{17} by Deuteron Bombardment.* W. W. CHUPP AND E. M. MCMILLAN, *University of California, Berkeley.*—The nucleus N^{17} offers a unique opportunity for studying many-particle reactions among the light elements, since its specific property of giving 4.13-sec. delayed neutrons allows it to be easily distinguished. We have examined the yield of delayed neutrons from a number of substances bombarded by an external beam of 195-Mev deuterons from the 184-inch cyclotron. The beam passed through a monitor consisting of a thin LiF crystal and then through a thin sample of known surface density; after 30 seconds of exposure the sample was allowed to fall into a sensitive re-entrant BF_3 chamber and the monitor was pulled alongside a BF_3 counter, and then simultaneous counts were taken for 30 seconds. The chambers were heavily shielded by paraffin to reduce background. Two kinds of measurements were taken: (1) comparisons of the relative yields per atom and (2) excitation curves as the deuterons were slowed down by copper absorbers between monitor and sample. The relative yields per atom show a roughly exponential decrease with the number of particles emitted, as indicated:

O not incl. O^{18}	F	Na	Mg	Al	Si	P	S	Cl	K
100,000	8400	2600	840	840	230	230	70	78	25

The excitation curves are monotonic with energy and show thresholds increasing with Z.

* This work was performed under the auspices of the Atomic Energy Commission.

F11. Properties of the 4-Second Neutron Emitter of Low Z. LUIS W. ALVAREZ, *University of California, Berkeley.*—A gas flow method has been used to show that a nitrogen isotope is responsible for the delay. The number of neutrons in the active nucleus is known from the work of Lawrence and Moyer, so the complete identification is N^{17}. In support of the Bohr-Wheeler hypothesis, "neutron-β" coincidences have been observed. The neutrons themselves are not detected, but instead, the recoiling O^{16} nuclei are observed in an atmospheric pressure proportional counter, through which passes a stream of He carrying the N^{17}. The pulse size distribution of the recoils gives directly the differential neutron distribution and this is observed to be very broad. Preliminary results show a maximum at zero energy, with a tail extending to more than 2 Mev. Its shape is probably due to the fifth power law of β-decay,

in which case it is not the true neutron width. Preliminary absorption measurements of the β-rays in coincidence with the neutrons indicate an upper limit of 2.7 ± 0.4 Mev. With the improved apparatus now in use, it should be possible to determine the neutron spectrum accurately and look for the expected variation of β-ray upper limit with neutron energy. This work was sponsored by the Atomic Energy Commission.

F12. On the Radioactive Decay of the Neutron. ARTHUR H. SNELL AND L. C. MILLER, *Clinton National Laboratories.*—A collimated beam of neutrons, three inches in diameter, emerges from the nuclear reactor and passes axially through a thin-walled, aluminum, evacuated cylindrical tank. A transverse magnetic field behind the thin entrance window cleans the beam of secondary electrons. Inside the vacuum, axially arranged, an open-sided cylindrical electrode is held at +4000 volts with respect to ground. Opposite the open side a smoothed graphite plate is held at −4400 volts. The field between these electrodes accelerates and focuses protons which may result from decay of neutrons, so that they pass through a $2\frac{1}{4} \times 1\frac{1}{4}$ inch aperture in the center of the graphite plate, and strike the first dynode of a secondary electron multiplier. The first dynode is specially enlarged so as to cover the aperture. Readings are taken (1) with and without a thin B^{10} shutter in the neutron beam; (2) with and without a thin foil over the multiplier aperture; (3) with and without the accelerating voltage. In a total counting rate of about 300 per min., about 100 are sensitive to operations (1), (2), and (3). In the absence of the accelerating field or with the foil (2) in, operation (1) does not change the counting rate. Assuming all of the 100 c.p.m. to be due to decay protons, preliminary estimates of the collecting and counting efficiency (10 percent) and of the number of neutrons in the sample (4×10^4) give for the neutron a half-life of about 30 minutes. It is at present much safer however to say that the neutron half-life must exceed 15 minutes. Coincidences are presently being sought between the disintegration betas and the collected protons.

THURSDAY AFTERNOON AT 2:15

East Building Lecture Room

National Bureau of Standards

(W. SHOCKLEY presiding)

Solid-State Physics Including Semi-Conductors

G1. Work Function and Semiconductors at High Temperatures. P. H. MILLER, JR. AND J. J. MARKHAM, *University of Pennsylvania.*—Bardeen's[1] theory of surface states has been extended to include the influence of the intrinsic electrons and holes at high temperatures on the behavior of the potential barrier near the surface of a semiconductor. Because of the high density of electrons and holes at very high temperature, the barrier potential must be very small and not influenced by the surface states (assumed density 10^{14} cm^{-2} volt^{-1}). Smith and Miller[2] found that work functions of N and P type silicon are independent of temperature and are approximately the same. This was interpreted as indicating that the height to which the surface states are filled is the same for both N and P type material but not necessarily at a point half-way between the filled and unfilled bands. The extended theory shows that this point is about halfway between the two bands.

[1] J. Bardeen, Phys. Rev. **71**, 720 (1947).
[2] A. H. Smith and P. H. Miller, Jr., Bull. Am. Phys. Soc. **23**, No. 2, p. 25.

G2. Hall Effect in Tellurium Measured by a.c. Method.* VIRGIL E. BOTTOM, *Purdue University.*—In order to eliminate the contribution from the Ettingshausen effects an a.c. method for measuring the Hall effect has been developed. Frequencies used have been between 1000 and 10,000 cycles per second, since in this range the Hall effect has been found to be independent of frequency. The circuit allows the measurement of both high and low resistivity samples and the Hall e.m.f. may be observed directly on the screen of an oscilloscope. Thus upon heating the sample it is possible to follow visually the change in the number of electrons as a function of temperature as determined from the Hall effect. Applied to various samples of tellurium, both commercial and especially purified, it has been found that the Hall effect is positive between the temperatures 20° and 400°C, with a slope indicating an activation energy in agreement with the value reported[1] for tellurium films.

* This work has been supported by Signal Corps contract.
[1] Wayne Scanlon and K. Lark-Horovitz, Phys. Rev. **72**, 530 (1947).

G3. Dependence of Resistivity of Germanium on Electric Field.* RALPH BRAY, *Purdue University.*—High resistivity ($\rho \sim 1$ ohm-cm) germanium samples, macroscopically uniform, are ohmic only up to fields of the order of 100 v/cm;[1] the critical field, E_c, above which the resistivity decreases, and the functional relation between the resistivity and field, $\rho(E)$, vary from sample to sample. Constant current pulses of 5-microsecond duration are used, thereby eliminating heating effects, and also determining the time constant for the field effect ($\sim 10^{-7}$ sec.). Studies

of the temperature dependence with both p and n type samples show that the maximum in the field effect occurs at a temperature corresponding to the transition from impurity to intrinsic conduction; the field effect diminishes rapidly on either side of the maximum. E_c and $\rho(E)$ are also temperature dependent. Secondary field effects with much longer time constants and giving first increasing and then decreasing resistivity with increasing field become important at the higher temperatures. To determine how far the field changes the number of carriers or their mobility, Hall effect measurements using these pulses have been started.

* Supported by Signal Corps.
[1] R. Bray, K. Lark-Horovitz, and R. N. Smith, Phys. Rev. 72, 530 (1947).

G4. Electronic States in Almost Periodic Systems. HUBERT M. JAMES, *Purdue University.*—The effects on electronic states in crystals of local disturbances (impurity atoms or local charge distributions; termination of the crystal at free surfaces) have heretofore usually been discussed by a fusion of particle and wave concepts. Many results thus obtained are open to criticism. A complete wave-mechanical analysis of such systems has therefore been made in the one-dimensional case. If the perturbing potential varies slowly, the wave functions are almost periodic functions with the period of the crystal potential, modulated by multiplying factors which are solutions of wave equations for effective potentials not in general identical with the perturbing potential. This analysis shows that the exclusion principle has in the past been improperly applied in discussing impurity states of crystals. It also makes possible a reliable qualitative discussion of impurity and surface states. Local depressions of potential may cause one or more trapping states to occur below each electronic band; a local rise in potential produces similar states above the bands. Localized surface states may occur with energies above or below the electronic bands; the electrons are trapped on the surface by image forces acting in conjunction with the perfectly reflecting crystal.

G5. Electrical Breakdown in LiF below Room Temperature. J. W. DAVISSON, *Naval Research Laboratory.*—Evidence will be presented to show that the star patterns formed by dielectric breakdown in LiF,[1] which lie at an azimuth of 12° at room temperature, do not reduce azimuth in a continuous manner with decrease of temperature. Statistical counting of the paths shows that only discrete orientations are permitted in this temperature range. This behavior further supports the notion that the star patterns do not represent merely an average direction formed by competative breakdown in the [110] and [111] directions. The general problem of breakdown will be summarized.

[1] Phys. Rev. 73, (1948).

G6. The Change in the Electrical Resistance Produced by Cold-Work. J. S. KOEHLER, *Carnegie Institute of Technology.*—Experimentally the electrical resistance of most metals increases by a few percent when they are cold-worked at room temperature. The present calculations are designed to decide whether this increase in the electrical resistance can be correlated with the increase in the density of dislocations which occurs during cold-work. The changes which take place in the dislocation density can be calculated from the changes in the yield stress. The dislocation contribution to the electrical resistance can be calculated if the relaxation time t associated with dislocation scattering is known. The first step in obtaining t is the calculation of the matrix element $V(kk')$ which gives the probability per unit time that a free electron of wave number k makes a transition to wave number k' as a result of the perturbation of the crystal lattice produced by the introduction of the dislocations. This matrix element is then used in the usual Bloch integral equation which determines t. The results obtained are that: The relaxation time t depends on the relative orientation of the electric field which produces the current and the dislocations. This directional dependence of the added resistance can be seen to be qualitatively reasonable. The calculated additional resistance introduced by cold-working copper at room temperature is 0.1 percent. Possible reasons for the discrepancy will be discussed.

G7. Measurement of Secondary Emission of Insulators at Low Primary Energies. PAUL K. WEIMER, *Radio Corporation of America.*—Published data on the secondary emission of insulators at primary energies of less than 20 volts are meager.[1] Experimental difficulties caused by charging of the test surface and poor alignment of the incident beam are encountered. An experimental method based on the electron optical techniques used in television camera tubes[2] has been developed. The sample is scanned by the primary beam and the returning electrons passed into an electron multiplier. The output signal is fed into a television viewing tube, providing a visual means of aligning and centering the beam. A pulsing technique with a saw-tooth voltage on the sample maintains charge equilibrium and permits the study of thick samples. The curve of secondary emission *vs.* primary energy is presented directly on an oscilloscope screen in a form convenient for study of fine structure in the curve. Measurements have been made on glass, silica, and various metals. One measurement on G.8 glass gave a ratio at 2-volts primary energy of 0.7 which was reduced to 0.3 on evaporation of a layer of silver too thin to be conducting.

[1] G. Maurer, Zeits. f. Physik 118, 122 (1941).
[2] A. Rose, P. K. Weimer, and H. B. Law, Proc. I.R.E. 34, 424 (1926).

G8. Production and Tests of Metal Single Crystal Surfaces.* H. E. FARNSWORTH, *Brown University.*—A summary is given by various methods of etching metal crystal surfaces so as to obtain a geometrical boundary parallel to a given set of planes for investigations in surface physics and chemistry. When some crystals are etched chemically under conditions favorable to the production of the desired surface, a thin polycrystalline layer is deposited on the surface during the process. In some cases this layer is soluble in certain solutions and hence may be dissolved, or it may be removed by heat treatment in vacuum.

Recent tests on the etching of a silver crystal by the method of electrolytic polish indicate that in this case this layer is not removed by subsequent thermal treatment. Tests by optical and electron diffraction methods are described.

* A part of this work was assisted by the Office of Naval Research.

G9. Sintering Process Study by Electron Micrography. H. CHRISTENSEN AND C. J. CALBICK, *Bell Telephone Laboratories.*—Thin flakes of nickel-manganese oxide originally composed of two interdispersed particle size ranges were studied by means of silica replicas of their free surfaces. These flakes were heated to selected temperatures in the sintering range 720° to 1300°C, then rapidly cooled. Below about 900°C the micrographs show incorporation of smaller particles into larger ones. From 900°C to 1200°C, the larger grains continue to grow with development of a terraced surface structure. Above 1200° the simple terraced structure tends to break down into a double terraced structure. Sometimes the terraces continue across a grain boundary, undergoing a sharp change in direction because of the change in crystallographic orientation. The height of one terrace above another is in the range 10^{-6} to 2×10^{-5} cm. These phenomena are not inconsistent with Frenkel's views[1] that surface tension is responsible for viscous flow of material from smaller particles to adjacent larger particles and also that surface flow can occur in a "two-dimensional" gas phase.

[1] J. Frenkel, J. Phys. U.S.S.R. **9**, 385, 392 (1945).

G10. Stress Relaxation by Interstitial Atomic Diffusion in Tantalum. T'ING-SUI KÊ, *University of Chicago.*—In a preceding report,[1] it was shown that the internal friction peaks observed in tantalum containing small amounts of C and O are caused by the stress—induced preferential distributions of C or O among the interstices in tantalum. In order to further elucidate this viewpoint, the relaxation strength associated with these relaxations has been determined by rigidity and stress relaxation measurements in torsion covering a wide range of temperature. When the reciprocal of relaxation strength is plotted against absolute temperature, the graph is a straight line through the origin. This linear relationship agrees with that predicted by theory, assuming a model of stress-induced preferential distribution. The finding that the extrapolated line passes through absolute zero shows that the interaction between solute atoms is negligibly small. This implies that the critical temperature for self-induced preferential distributions of solute atoms is close to absolute zero in the present case.

[1] T. S. Kê, Bull. Am. Phys. Soc. (December 1947).

G11. A Theoretical Approach to the Strength of Materials Under Cyclic Loading. EDWARD SAIBEL, *Carnegie Institute of Technology.*—In a previous paper* the author has derived a theoretical relationship between the time it takes a material to fracture under a steady load and the applied stress. This derivation, based on the Eyring theory of reaction rates, considered the breaking of bonds between ions or atoms as the product of the reaction and took into account in an approximate manner the effect on the remaining system of the net product of the reaction. This work is extended to the cyclic loading of a material and an approximate relationship of the form $s=A-BT(\log N-C)$ is found; where s is the stress amplitude, N is the number of cycles to fracture, T is the absolute temperature, and A, B, and C are constants characteristic of the material.

* Edward Saibel, J. Chem. Phys. **15**, 760 (1947).

G12. Adsorption of Mercury by Activated Carbon. R. C. MASON, *Westinghouse Research Laboratories.*—The early observations of Coolidge[1] on the adsorption of mercury vapor by activated carbon have been confirmed by extensive experiments on adsorption between −5°C and 100°C. A special ion gauge was used to measure the vapor density, and the amount of mercury adsorbed was determined by direct weighing. The density of mercury atoms in equilibrium with the adsorbed phase could be represented by

$$n=Dw\epsilon^{-Q/RT},$$

where n is the number of atoms per cm³, w is the weight of mercury adsorbed in milligrams per gram of carbon, and Q is the differential heat of adsorption. For a number of different carbons, Q was found to be approximately 10,000 calories per mole, and D to be of the magnitude of 10^{21}.

From the kinetics of the adsorption, some conclusions about the nature of adsorption and the structure of the carbon may be drawn.

[1] J. Am. Chem. Soc. **49**, 1949 (1927).

THURSDAY AFTERNOON AT 2:15

Hall of Government, Room 1

(F. W. LOOMIS presiding)

More or Less Thermal; Mass-Spectra of Ions

H1. Redefinition of the Thermodynamic Scale of Temperatures. F. G. BRICKWEDDE, *National Bureau of Standards.*—In 1939 Giauque urged that we proceed to redefine the number scale of the present thermodynamic temperature scale as recommended by Joule and Thomson. The new number scale would be determined by assigning a number to the temperature (T_0) of the ice point (ordinary freezing point or triple point) on the absolute scale (scale

on which the lowest possible temperature is 0°). By assigning to the ice point the present best value (~273.16) on the present Kelvin scale, the newly defined and presently used thermodynamic scale would be the same, to within the present accuracy, of the best gas thermometer measurements. The steam point (100°C) would be reduced to the status of other secondary thermometric fixed points. The new definition would fix the number difference (~273.16°) between the absolute (or new Kelvin) and centigrade scales. Fixing by definition the numerical value ($1/T_0$) of the temperature coefficient of volume and pressure changes of the *ideal* gas (now an empirical constant) had other advantages: (1) the accuracy of temperature determinations with gas thermometers would be improved, and (2) the necessity would be removed of recomputing (by methods not agreed upon) previously determined temperatures whenever a different empirical value is used for the fundamental temperature coefficient of the ideal gas.

H2. The Viscosity of D_2O and of H_2O from 5° to 125°C.* R. C. HARDY AND R. L. COTTINGTON, *National Bureau of Standards (Introduced by F. G. Brickwedde).*—Measurements of the absolute viscosity of D_2O of 99.5 percent purity and of H_2O were made over the temperature range 5° to 125°C. The work also included determinations of the density of D_2O over the temperature range 90° to 125°C. Values for the viscosity and density of 100 percent D_2O with 0.7-atom percent excess O^{18} were obtained by linear extrapolation. A Bingham variable pressure viscometer was used in the range 5° to 95°C. This instrument was calibrated with water at 20°C using the value 1.005 centipoise for the viscosity of water at this temperature. A modification of the Ostwald viscometer, with equal air pressure applied to both limbs to prevent boiling, was used at the higher temperatures. This instrument was calibrated with water at several temperatures using viscosity values determined with the Bingham instrument. The ratio of the viscosity of D_2O to that of ordinary water at the same temperature was found to be 1.3052 at 5°C. This ratio decreased at a diminishing rate with an increase in temperature to a value of 1.1456 at 125°C.

* This work supported in part by Atomic Energy Commission.

H3. Heats of Vaporization of Uranium Hexafluoride. J. F. MASI, *National Bureau of Standards (Introduced by F. G. Brickwedde).*—Measurements of heats of vaporization of uranium hexafluoride have been made from 4° to 90°C to complete the work on thermodynamic properties of this important substance. A heavy-walled copper vaporization chamber, nickel-plated on the inside, was enclosed in a vacuum jacket which was surrounded with a bath maintained within 0.002°C of any desired temperature. The temperature of the emergent vapor was obtained from a nickel resistance thermometer on the exit tube. The apparatus was tested by obtaining the heat of vaporization of water at 60° and 95°C; the results obtained were scattered uniformly about the values given by Osborne, Stimson, and Ginnings,[1] with a spread of about 0.3 percent at 60° and 0.1 percent at 95°. The heats of vaporization of UF_6 were measured at seven temperatures from 4°C to the triple point (64.05°C) and at four temperatures above the triple point. Six samples of UF_6 were used, all from the same original source and all purified in the same manner. The experimental heats of vaporization had a precision of ±0.5 percent for the solid and about ±1.0 percent for the liquid. There is agreement, within experimental error, with values calculated from the vapor pressure equation of Crist and Weinstock (to be published in J. Chem. Phys.), except at temperatures below 35°C.

[1] N. S. Osborne, H. F. Stimson, and D. C. Ginnings, *J. Res. Nat. Bur. Standards*, 23, 197–260 (1939).

H4. The Vapor Pressure of O_2 from the Triple Point to the Critical Point. HAROLD J. HOGE, *National Bureau of Standards.*—The vapor pressure of O_2 has been measured over the entire liquid range. Low pressures were measured with a mercury manometer, intermediate and high pressures with a piston gage. Temperatures were measured with a platinum resistance thermometer. Vapor pressures in the neighborhood of the normal boiling point agree rather well with previously accepted values. At high pressures the data are somewhat lower than the 1914 values of Onnes, Dorsman, and Holst. Part of the disagreement is probably due to a difference in temperature scales. The triple point temperature was found to be 54.363°K. A calorimetric method was used to determine the critical temperature and to show whether or not the equilibrium chamber contained both liquid and vapor. If either phase disappears, the heat capacity drops sharply. Hence so long as the heat capacity remains high there are two phases in the equilibrium chamber and vapor-pressure measurements may be made. The highest temperature at which the drop in heat capacity occurs was found by varying the quantity of material in the apparatus. This temperature, about 154.5°K, is the critical temperature as calorimetrically determined.

H5. A Photoelectric Pyrometer for the Measurement of Luminous Flame Temperatures. J. A. SANDERSON, J. A. CURCIO, AND DOROTHY V. ESTES, *Naval Research Laboratory.*—A photoelectric pyrometer has been developed for the measurement of flame temperatures by a method suggested by Hottel and Broughton.[1] By means of a photomultiplier tube, RCA 1-P22, covered with an interference filter transmitting a spectral band 140A wide at λ5520A, radiant intensities of luminous gas-oxygen flames were measured first against a dark background and then with a mirror of reflectivity R so placed behind the flame that radiation was retrodirected, thus, in effect, increasing the flame thickness. The photo-cell filter system was calibrated with radiation from a ribbon filament tungsten lamp at known temperatures. Application of Wien's and Kirchoff's radiation laws provided a relation between photo-cell currents and true flame temperature. Flame temperatures determined by this method were about 10 to 15 percent lower than temperatures obtained by line reversal, presumably because the latter method gave a result for the hottest part of the flame, while the pyrometer gave a result for the integrated radiation emitted by the entire

thickness of the flame. Typical temperatures of a gas-oxygen torch were: pyrometer 1758°K; line reversal 1945°K.

[1] H. C. Hottel and F. P. Broughton, Ind. and Eng. Chem. Anal. Ed. 4, 166 (1932).

H6. Measurement of Gas Temperatures in the Exhaust Flames of Rocket Motors by Spectroscopic Methods. I. H. M. STRONG AND F. P. BUNDY, *General Electric.*—In measuring the temperature of the exhaust gases of a rocket motor, it is necessary to use a physical optical method that does not disturb the flow of the gases. Because of the hazardous nature of the combustion, all observations must be made by remote control. An apparatus is described for measuring the temperature by the sodium line reversal method. A wide range of temperatures for the comparison radiator is provided by illuminating an optical wedge with a tungsten arc and focusing its image on the slit of the spectrograph. Reversal occurs on the wedge image at a place where the temperatures of the comparison radiator and the flame are equal. The results are recorded photographically in the spectrograph. The optical parts are all mounted on a rigid framework which is shock mounted inside of a protective box. All necessary settings are made through the use of solenoids. The effect of the complex flame structure, the width of the sodium line, and the resolving power of the spectrograph on the measurement of temperature will be discussed.

H7. Measurement of Gas Pressures in the Exhaust Flames of Rocket Motors by Spectroscopic Methods. II. F. P. BUNDY, A. B. GREGG, AND H. M. STRONG, *General Electric.*—The gases from rocket motors emerge from the exhaust nozzle at supersonic speed. The boundary conditions inside and just outside the nozzle usually cause a series of stationary shocks in the flame which are commonly known as "shock diamonds." Methods have been developed for measuring the temperatures and pressures in different parts of the flame structure by optical means which do not require any mechanical disturbance of the gas flow. This paper describes the method used for measuring the pressures. It is based upon the shift of wavelength of the sodium *D*-line radiation toward the red caused by the influence of the foreign gas molecules of the flame. This red shift effect is proportional to $pT^{-\frac{1}{2}}$, and depends upon the perturbing gas. The small shift of wavelength is measured from the change in diameter of the fringes of a Fabry-Perot interferometer. The effect has been calibrated by use of a special pressure flame chamber in the laboratory. The gas pressures at different places in a typical rocket flame are found to range from 0.8 atmospheres up to 2.5 atmospheres.

H8. Determination of Detonation Temperatures in High Explosives.[1] R. L. BOYER.[2]—Theoretical evaluation of the high pressures and temperatures of the detonation wave in solid explosives has been based on experimental values of the rates of detonation at various loading densities and an assumed form of the equation of state. The calculated temperatures vary with the loading density, and depend upon the particular assumptions made in the equation of state. An experimental method has been developed to determine detonation temperatures. The radiant energy emitted by the detonating explosive is readily detected for narrow spectral ranges by sensitive phototubes and the time record of the radiation is obtained by photographing the sweep trace of a cathode-ray oscilloscope with the phototube circuits connected to the vertical deflection plates. Preliminary results are given for the detonation temperatures of pentaerythritol tetranitrate powders at several loading densities which indicate a decrease in detonation temperature with increasing loading density in agreement with predictions based on the Kistiakowsky-Wilson equation of state.

[1] This research is part of the work being done ot the Bureau of Mines, supported by the Office of Naval Research.
[2] Physicist, Explosives Research Section, Bureau of Mines, Pittsburgh, Pa.

H9. Radio Frequency Mass Spectrometer. WILLARD H. BENNETT, *National Bureau of Standards.*—Studies of the origins of negative ions are made difficult by the fact that dissociation cross sections for such ions are generally much larger than atomic and molecular ionization cross sections because the electron attachment energies for negative ions are generally small. To separate and identify negative ions, it is essential that the negative ions be required to travel a much shorter distance than the particles have to travel in the familiar kinds of mass spectrometers using magnetic resolution of beams. A six-electrode tube with cylindrical symmetry has been developed, in which an adjustable radio frequency is applied to the second grid. A mass resolution is obtained which is adequate for many kinds of negative ion studies. By extending the method to two stages in a nine-electrode tube, either with cylindrical or parallel plane electrodes, and applying the radio frequency to two of the grids, a higher order mass resolution is obtained which is generally usable in the mass spectrometry of positive ions, and in ionization studies as well as in the present negative ion investigations.

H10. Ionization Efficiency Curves from Mass Spectrometer Data. S. N. FONER, A. KOSSIAKOFF AND F. T. MCCLURE, *Johns Hopkins University.*—A theoretical treatment is developed which provides a method of eliminating the effect of the thermal spread of electrons on the appearance potential curves obtained with a mass spectrometer. Thus it is possible to derive the ionization efficiency curves from the appearance potential curves without *a priori* assumptions regarding the nature of the former. The relationship between these curves is given by $P(V)=I(V)-2kTI'(V)+k^2T^2I''(V)$, where $P(V)$ is proportional to the ionization efficiency for electrons of energy V, $I(V)$ is the ion current obtained with an accelerating voltage V, primes indicate differentiation, and the other symbols have their usual significance. Other experimental influences affecting the observed appearance potential curves are discussed. The application of the methods is illustrated with experimental data on several of the rare gases.

H11. The Appearance Potential of Metastable Ions in Some Hydrocarbon Gases. R. E. Fox, A. Langer, and J. A. Hipple,* *Westinghouse Research Laboratories.*—The study of hydrocarbon spectra in a mass spectrometer has shown several diffuse peaks which have been attributed to metastable ions. These ions presumably are in an excited state, and it has been shown that they spontaneously dissociate during transit through the mass spectrometer tube with a half-life of about 10^{-6} seconds. A study of the appearance potential of some of these metastable peaks has been made in order to determine if any measurable excess energy is associated with the metastable condition. If no excess energy is involved, then the appearance potential of the metastable ion should agree with that of the parent ion in the dissociation process. The appearance potentials of peaks in the butanes, butenes and 1,3 butadiene were measured and the results will be presented which indicate that in most of the cases studied an excess energy of about 2 ev above the ionization level is required for the metastable state.

* Now located at National Bureau of Standards.

H12. Metastable Transitions in Mass Spectra of Hydrocarbons. Evelyn G. Bloom, Fred L. Mohler, J. H. Lengel and C. E. Wise, *National Bureau of Standards.*—Mass spectra of hydrocarbons show mass peaks of the parent ion and nearly all possible dissociation products and, in addition, small wide peaks at non-integral mass numbers which have been ascribed to ions which undergo dissociation after they have passed through the ion accelerating field. The apparent mass of these ions m_a is given by the relation $m_a = m_f^2/m_i$ where m_f is the final mass and m_i the initial mass.[1] In a systematic survey of 56 saturated and unsaturated hydrocarbons, 362 metastable transitions have been identified.[2] There are 32 different transitions involving loss of masses 2, 15, 16, 26, 27, 28, 29, 30, 42, and 44. Loss of mass 2 is by far the most common transition. The losses of masses 15 (CH_3), 29 (C_2H_5), and 30 (C_2H_6) come only from the parent molecule ions.

[1] Hipple, Fox and Condon, Phys. Rev. 69, 347 (1946).
[2] American Petroleum Inst. Catalog of Mass Spectral Data.

H13. Analysis of Solids by the Mass Spectrometer. W. M. Hickam, *Westinghouse Research Laboratories* (*Introduced by R. C. Mason*).—Solid samples of known weight introduced into the mass spectrometer tube are completely vaporized in a furnace. The resulting molecular beam is subjected to electron bombardment where the observed ion current for a given mass to charge ratio is a measure of the evaporation rate for that particular element. The integral of the ion current with respect to time is found to be proportional to the amount of the element present. Applying this method to the investigation of impurities in copper, sensitivity of one part impurity per million parts copper has been obtained on Sb, Se, As, and Ag when using two milligram samples. The high vapor pressure of these elements as compared to copper at the furnace temperature provide rapid vaporization and the resulting high sensitivity.

Thursday Afternoon at 2:15

National Academy of Sciences

(J. Schwinger presiding)

Theoretical and Experimental Nuclear Physics

I1. Some Deuteron Variational Methods. William Rarita, *Brooklyn College and Massachusetts Institute of Technology.*—We report some methods of calculating accurately the depths of different shape potentials of the deuteron for non-central forces. Starting with a square well we know the radial S and D wave functions u and w outside the well. Inside the range of interaction we assume a general expansion in terms of modes. These modes for u and w we take to be Bessel functions of order one-half and five-halves, respectively. The wave-lengths of these modes are determined by requiring the continuity of the logarithmic derivative. By using the variational principle for one mode and then two such modes we get 0.95 and 0.99 of the full binding energy. With an exponential times a power of the interparticle distance as our modes, we decided to relax the joining condition so as to require only continuity at the potential edge. The results for the square well were gratifying. For a meson potential, as the convergence seemed slow, we resorted to an iteration procedure lately developed by Feshbach and Schwinger to improve our initial three mode solution. A promising start was also made on the triton problem in which the wave function was allowed to have a discontinuous second derivative over a certain boundary.

I2. Comparison of Recent Methods in the Theory of Nuclear Reactions. T. Teichmann, *Princeton University.*—A comparison has been made of the resonance formula recently derived by a simple method by Feshbach, Peaslee, and Weisskopf[1] and the more general results on the same subject obtained by Wigner and Eisenbud.[2] In the treatment of reference 1 all processes other than scattering are lumped together as "absorption" and characterized by a single complex parameter; this parameter, as well as the phases, etc., is assumed to be a smooth function of the energy. As a consequence of these assumptions the absorp-

tion cross section goes to zero between each pair of resonances. According to the results of reference 2, this can only occur if the ratio of the partial widths corresponding to the emission of different γ-quanta, etc., is the same for all resonances. Mathematically speaking, this is due to the fact that a two-alternative process, for instance, is characterized in general by three real parameters which are simple functions of the energy,[4] while only two such functions are used in reference 1. While these particular consequences of reference 1 must be regarded as doubtful, the order of magnitude of the scattering cross section is correct, and that of the neutron width seems to be in reasonable agreement with experimental results, at any rate within a factor of 5.

[1] Feshbach, Peaslee, and Weisskopf, Phys. Rev. **71**, 147 (1947).
[2] E. P. Wigner, Phys. Rev. **70**, 606 (1946); E. P. Wigner and L. Eisenbud, Phys. Rev. **72**, 29 (1947).

I3. On Tensor Forces and the Variation-Iteration Method. H. FESHBACH, *Massachusetts Institute of Technology* AND J. EISENSTEIN AND J. S. SCHWINGER, *Harvard University*.—A complete exploration of the phenomenological theory of the deuteron employing a non-central forces has been hampered by the absence of a satisfactory method for the calculation of force constants for shapes other than the square well. In the present paper, the variation-iteration[1] method has been applied successfully to this problem. Given the shapes of the central and non-central forces, the well depths of each, V_0 and γV_0, respectively, are determined by the binding energy and quadrupole moment of the deuteron. A variational integral is constructed for V_0, γ being kept constant. There is a complication provided by the non-positive definiteness of the operators. Nevertheless, one can determine upper and lower bounds for V_0. The meson well shape has been used; the central force has the range r_0 determined by proton-proton scattering. The range of the non-central force was varied from r_0 to $2r_0$. V_0 was determined to one part in a thousand. V_0 decreases rapidly γ increases correspondingly with decreasing range of the non-central force. The changes are much sharper than those in the corresponding square well case. Other well shapes are being investigated.

[1] J. S. Schwinger, Phys. Rev. **72**, 742 (1947).

I4. Exchange Currents in Nuclei. R. G. SACHS, *University of Wisconsin*.—Recent measurements[1] of the magnetic moment of He^3 indicate[2] the existence of exchange currents in nuclei as suggested by Villars.[3] Villars successfully considered the exchange moment produced by a charge-bearing meson field which is known not to give a good account of nuclear forces. An attempt is made to avoid this difficulty by considering the phenomenological exchange forces as a starting point. It is found that an exchange current must be introduced to establish the equation of continuity for the current and charge density produced by the protons. This exchange current is substantially the same as that obtained by Siegert[4] on the assumption of a special type of charge-bearing field. Application to H^3 and He^3 indicates that the corresponding exchange moment is too small to account for the observed moments. This theory is expected to be somewhat more limited than a field theory since it takes no account of the detailed structure of nucleons.

[1] H. L. Anderson and A. Novick, private communication.
[2] R. G. Sachs, Bull. Am. Phys. Soc. **22**, 9 (1947).
[3] F. Villars, Phys. Rev. **72**, 256 (1947), Helv. Physica Acta **20**, 476 (1947).
[4] A. F. Siegert, Phys. Rev. **52**, 787 (1937).

I5. $d-p$ and $d-n$ Cross Sections. D. C. PEASLEE, *Massachusetts Institute of Technology*.—On the basis of a very simple model it is made plausible that the Oppenheimer-Phillips or stripping process is responsible for practically the entire observed $d-p$ cross section at any bombarding energy E_d. This is indicated by agreement between the few available quantitative $d-p$ excitation curves—for Na^{24}, Co^{59}, Cu^{63}, Br^{81}, and Bi^{209}—and computed curves, assuming that only the stripping process is effective. The observed decline of the excitation curves with increasing E_d at energies above the barrier height of the target nucleus is interpreted as the result of effective $d-n$ competition in which the excited nucleus re-emits the neutron acquired in the $d-p$ stripping process. Comparison of the observed cross section magnitudes with the calculated values involves specifying as a nuclear parameter the average "stricking probability" ξ of an elementary particle. It is expected that the $d-n$ excitation curves are also predominantly due to the stripping process for incident energies $E_d \gtrsim 10$ Mev. Comparison of the $d-p$ and $d-n$ stripping processes indicates that the observed ratio σ_{dp}/σ_{dn} will exceed unity at all energies E_d comparable with or below the target Coulomb barrier and may approach the limit $\sigma_{dp}/\sigma_{dn} \to \xi_n/\xi_p \approx 1$ as $E_d \to \infty$.

I6. Interference Effects in Angular Correlations. D. S. LING* AND D. L. FALKOFF,** *University of Michigan*.—The selection rules for nuclear transitions allow the simultaneous emission of radiation of different orders. Between such allowed radiations there exists the possibility of interference effects in the angular distribution and total intensity of the radiation. Most important is the simultaneous emission of electric 2^l and magnetic 2^{l-1} pole radiation since their intensities can be of the same order. We find that for a single transition there is no interference either in the total radiation or in its angular distribution. However, in cascade transitions, interference effects can radically alter the angular correlation. For example, for $\gamma-\gamma$ correlation with the first transition pure dipole and the second a mixture of electric quadrupole and magnetic dipole and with the angular momentum of successive states $J+1$, J, and $J-1$, the correlation is:

$$W(\theta)=1+\frac{28+3(J-1)(J-5)\alpha^2+84(J-1)\alpha}{364+(J-1)(55J+61)\alpha^2-28(J-1)\alpha}\cos^2\theta.$$

α^2 is essentially the ratio of quadrupole to dipole intensity. The terms involving α arise from interference.

* Rackham Pre-Doctoral Fellow.
** National Research Council Fellow.

I7. Preliminary Results of a He^6 Neutrino Experiment.* JAMES S. ALLEN, H. R. PANETH, AND A. H. MORRISH, *University of Chicago*.—An intense source of He^6 has been developed through the use of the Be^9 (n, α) He^6 reaction. The source consists of one pound of beryllium powder in a

metal can placed near the target of the University of Chicago cyclotron. The He^6 gas is swept out of the powder by alcohol vapor and carried through a pipe line to the recoil chamber. The nuclear recoils resulting from the disintegration of He^6 are detected by means of an electron multiplier tube and the β-rays by an end-window Geiger counter. The energy spectrum of the recoils is studied by recording coincidences between the two detectors as a function of the retarding potential between a set of grids in the path of the recoils. The recoil spectrum observed for 180° coincidences has a maximum energy of approximately 1400 ev. The shape of the spectrum suggests that the angular correlation between the electron and neutrino follows a $(1-\beta\cos\theta)$ law. An investigation of the effect of the geometry of the apparatus upon the shape of the spectrum is being made.

* This research was supported by the Office of Naval Research.

I8. Proposed Nuclear Reactions Involving Polarized Protons. LINCOLN WOLFENSTEIN, *University of Chicago.*—Calculations have been made on several proposed methods for producing and using polarized beams of protons. Methods of production include (a) the (n, p) reactions of N^{14} and He^3, using polarized thermal neutrons, and (b) the resonant scattering of protons from helium.[1] The method (b) will produce higher energies and intensities but is possible only if a P resonance is actually involved. The percentage polarization depends on the ratio of the $^3P_{3/2}-{}^3P_{1/2}$ splitting to the resonance width, a 45 percent polarization corresponding to a ratio as small as 0.1. The following reactions employing polarized protons were considered: (1) $Li^7+p\rightarrow 2He^4$ and (2) proton-proton scattering. In general, the effect on a reaction of using protons (or neutrons) polarized perpendicular to their axis of incidence is to introduce a left-right asymmetry in the outgoing intensity. Thus, in case (1) the polarization introduces an appreciable term $C\sin\theta\cos\theta\sin\phi$ in the angular distribution of the alpha-particles. For the proton-proton case, the polarization effect is very small, less than 1 percent for energies up to 2.5 Mev. Finally, polarization is shown to persist in the slowing down of protons.

[1] Compare J. Schwinger, Phys. Rev. **69**, 681 (1946).

I9. Nuclear Magnetic Moments and Meson Exchange. P. MORRISON, *Cornell University.*—Villars[1] has emphasized the importance of the contribution to the magnetic moments of nuclei made by the exchange of mesons between nucleons. Attempts to explain the observed magnetic moment of the triton by considering only the spin and orbital moments of the nucleons[2] require the use of wave functions with large admixtures of high orbital states. It seems probable that the difference between proton and triton magnetic moment includes an exchange contribution. We ask how far the form of meson theory adopted affects the exchange magnetic moment for light nuclei. For nuclear states in which there is no orbital angular momentum, these statements hold for quite general forms of meson-nucleon coupling: (a) The exchange current contribution to the magnetic moment of deuteron and alpha particle is strictly zero, but is finite for the case of the nuclei of mass three, and (b) the sum of the magnetic moments of triton and He^3 is equal to the magnetic moment of the deuteron. These conclusions follow from symmetry arguments alone for any meson-nuclear coupling in which positive and negative mesons are coupled to nucleons with equal strength. The sign and magnitude of the exhange effect in either H^3 or He^3 depends on the form of coupling, but the details of the wave function can affect even the sign of the result. Orbital motion will produce additional effects.

[1] F. Villars, Phys. Rev. **72**, 256(L) (1947).
[2] R. G. Sachs, Bull. Am. Phys. Soc. **22**, 9 (1947).

I10. Polarization Effects in Ionization Loss of Fast Particles.* FRANK L. HEREFORD, *Bartol Research Foundation.*—The effect of the polarization properties of a medium on the ionization energy loss of fast charged particles (suggested by W. F. G. Swann) has been investigated theoretically by Fermi and recently by Halpern and Hall.[1] Whereas previously published curves predict an appreciable effect only at energies of about 20 m_0c^2 and higher, Halpern and Hall indicate that in the case of 1-Mev electrons traversing carbon, the reduction in loss caused by polarization is approximately 8 percent. By measuring the relative stopping powers of carbon and H_2O with a double coincidence train of thin wall (0.035 g/cm²) counters, this reduction has been confirmed. The observed stopping power ratio, $^SH_2O/S_c$, was $1.18\pm.02$ compared with 1.16 (Halpern-Hall) and 1.08 (Bethe-Bloch). Scattering difficulties were minimized by choosing equal thicknesses (in radiation lengths) of carbon and H_2O for comparison. This effects equal scattering[2] in the specimens without seriously altering the energy distribution of the particles suffering loss. It is thus fortuitously favorable situation in the case of carbon and H_2O which makes the experiment feasible.

* Assisted by the Office of Naval Research.
[1] O. Halpern and H. Hall, Phys. Rev. **73**, 477 (1948).
[2] B. Rossi and K. Greisen, Rev. Mod. Phys. **13**, 264 (1941).

I11. Variation of He^3/He^4 Abundance Ratio in Natural Sources of Helium. L. T. ALDRICH AND ALFRED O. NIER, *University of Minnesota.*—As an extension of the mass spectrometer work reported earlier,[1] an investigation of the He^3/He^4 ratio in helium obtained from radioactive ores, beryl crystals, and natural gas has been undertaken. No He^3 peak was observed in any of the five radioactive samples studied and if He^3 exists in these, the He^3/He^4 ratio is less than 0.3×10^{-7}. The He^3/He^4 ratios in seven beryl samples varied from 0.5 to 10.5×10^{-7}. Samples from four natural gas wells in the vicinity of Amarillo, Texas gave He^3/He^4 ratios of 0.6, 1.4, 1.4, and 2.0×10^{-7}, respectively. These values are to be compared with ratios of 1.4 and 12.0×10^{-7} found for commercially obtained well and atmospheric helium, respectively. The precision of measurement in all this work was such as to leave no doubt that significant differences in He^3 concentration exist.

[1] L. T. Aldrich and A. O. Nier, Phys. Rev. **70**, 983 (1946).

I12. Packing Fraction Measurements of the Heavy Elements. A. J. DEMPSTER, *Argonne National Laboratory.*

—The resolving power of the double focusing mass spectrograph, previously used for comparing the masses of the isotopes of the heavy elements, has been increased about ten times. The ions are produced by electron ionization of the vapor of the metal or volatile metallic compounds using 1000 volt electrons. Ions with high multiple charges are produced with sufficient intensity in this manner.* A new electrode arrangement for accelerating and focusing the ions has been adapted for use with 15,000-volt accelerating potentials. The resolution obtained will be illustrated by photographs of the mass spectra of zinc showing $_{64}Zn^{++}$, O^+, NH_2^+, and CH_4^+ ions at mass 16, and $_{66}Zn^{++}$, OH^+, and NH_2^+ ions at mass 17. From these comparisons mass values may be found for the zinc isotopes which give preliminary packing fractions of -7.68×10^{-4} for Zn^{64} and -7.64×10^{-4} for Zn^{66}.

* A. E. Shaw, Phys. Rev. (in press).

I13. Ranges in Air and Mass Identification of Plutonium Fission Fragments. S. KATCOFF, J. A. MISKEL, AND C. W. STANLEY, *Los Alamos.*—Determinations were made of the mean and extrapolated ranges in air of plutonium fission fragments for twenty individual masses between 83 and 157. Collimated fission fragments passing through air at 120 or 140-mm pressure were deposited, after being stopped by the air, on a series of 14 thin lacquer films. These were analyzed radiochemically for individual fission products. The corrected activities were plotted against distance traversed by the fragments, yielding differential range curves whose widths of half-maximum were 11.7 ± 1.3 percent, independent of fragment mass. The activities found beyond each distance were plotted against distance giving integral range curves. Mean and extrapolated ranges were derived from these. In the light group the extrapolated ranges decrease from 2.90 cm (15°C and 760 mm) for mass 83 to 2.25 cm for mass 117; in the heavy group they decrease from 2.25 cm for mass 127 to 1.95 cm for mass 157. From the range-mass curve drawn for well-known masses, definite assignments of 92, 93, and 132 were given to 3.5-hr. Y, 10-hr. Y, and 77-hr. Te, respectively. Highly probable assignments of 94 and 134 were given to 20-min. Y and 54-min. I, respectively.

I14. Stopping of Fission Fragments. W. M. GOOD, E. O. WOLLAN, AND W. A. STRAUSER, *Oak Ridge National Laboratory.*—A study is being made of the range in air and other gases of the fission fragments which are responsible for the 4.5-sec., 22-sec., and 55-sec. delayed neutron activities. The apparatus consists of a special gas tight chamber ("rabbit") which contains a fission foil, a collector button, a gas sealing button, and a filling valve. This rabbit is sent in and out of the Clinton pile in a pneumatic tube, and the catcher button is automatically removed from the assembly on exit from the pile and sent into a counter assembly where the delayed neutron activity is counted as a function of time after irradiation of the gas pressure in the rabbit. The apparatus will be described in detail. To date results have been obtained on the range in air of the above-mentioned fission fragments from both U^{235} and U^{233}. These results are listed in Table I.

TABLE I.

	4.5 sec.	22 sec.	55 sec.
235	3.13±0.03 mg/cm air	2.33±0.02	3.19±0.03
233	3.16±0.03	2.33±0.02	3.16±0.03

THURSDAY EVENING AT 7:00

Sapphire Room, Mayflower Hotel

(J. R. OPPENHEIMER presiding)

Banquet of the American Physical Society

Presentation of the Duddell Medal of The Physical Society of London by Ambassador Lord Inverchapel to R. T. Van de Graaff.

After-dinner speech by R. W. Wood.

Chamber Music

FRIDAY MORNING AT 10:00

Lisner Auditorium

(S. K. ALLISON presiding)

Reactions of Transmutation

J1. The Ratio of Deuterium to Beryllium Photo-Disintegration Thresholds. BERNARD WALDMAN AND WALTER C. MILLER, *University of Notre Dame.*—We have measured the ratio of the deuterium to beryllium photodisintegration thresholds. Electrons, accelerated in a pressure electrostatic generator, were used to produce x-rays in a thick gold target. The neutrons were detected with a boron trifluoride proportional counter, a fast pulse amplifier, and a synchroscope. The electron energy was measured by a null type generating voltmeter. An off-

balance voltage of one kilovolt could be detected. The observed ratio is 1.338±0.004. This measurement assumes the linearity of the generating voltmeter. Our ratio is consistent with the results quoted in Stephens summary.[1] No attempt has been made to calibrate the voltmeter on an absolute scale. This research was supported by the Office of Naval Research.

[1] W. E. Stephens, Rev. Mod. Phys. 19, 19 (1947).

J2. On the Angular Distribution of Protons from the Photo-Disintegration of the Deuteron.[1] W. M. Woodward[2] and I. Halpern, *Massachusetts Institute of Technology.*—The new pressure electrostatic generator at M.I.T. is used as a source of γ-rays (up to 3 Mev) to investigate the photo-disintegration of the deuteron. The protons from the reaction are detected by means of three proportional counters, connected in coincidence and anticoincidence, which are mounted on a radius through the deuteron target and can be rotated about it. The arrangement permits measuring simultaneously the range and direction of the disintegration protons. The deuteron target and the counters are housed in a single chamber and deuterium gas serves both as the source of deuterons and as the counter gas. This eliminates any windows which would stop low energy protons and makes it possible to work down to within 200 kv of the threshold. The principal experimental difficulty was detecting the low energy protons in the presence of the large γ-ray background from the generator. The proper choice of counter design, and of electron target for the production of γ-rays, plus an optimum amount of lead, make this possible. Very preliminary results yield rough agreement with the theory of Bethe and Peierls at 2.6 and 2.75 Mev.

[1] Work assisted in part by Office of Naval Research.
[2] Now at Cornell University, Ithaca, New York.

J3. Photoelectric Production of Protons in Nuclei. E. D. Courant, *Cornell University.*—Recent experiments[1] show that the ratio of (γ, p) to (γ, n) cross sections in medium nuclei with 17-Mev γ-rays is considerably higher than is to be expected from the statistical theory.[2] This may be explained by noting that, instead of interacting with the nucleus as a whole and forming a compound nucleus, the γ-ray may be absorbed by dipole interaction with a single proton, which is ejected immediately. The cross section for this process may be small compared to that for the formation of a compound nucleus, but large compared to that for the emission of a proton from the compound nucleus. The cross section has been estimated by regarding the nucleus as a Fermi gas and using the theory of the surface photoelectric effect in metals.[3] It is found that this model yields $(\gamma-p)$ cross sections of the right order of magnitude to account for the experiments. More accurate calculations are in progress.

[1] Hirzel and Wäffler, Helv. Phys. Acta 20, 373 (1947).
[2] Weisskopf and Ewing, Phys. Rev. 57, 472 (1940).
[3] Mitchell, Proc. Roy. Soc. 146A, 442 (1934).

J4. Angular Distributions of Neutrons from (d, n) Reactions. C. E. Falk, E. Creutz, and F. Seitz, *Carnegie Institute of Technology.*—Using threshold detectors and 15-Mev deuterons from the University of Pittsburgh cyclotron, angular distributions of neutron groups from about 7 to 25 Mev from various targets have been observed. A large excess of neutrons is found in the forward direction of the incident deuteron beam. This observation is in general agreement with the work of Roberts and Abelson[1] who found large ratios of the neutron yields at 0° to those at 90°. The half-widths of our angular distributions as measured with threshold detectors can be roughly explained in the case of a copper target by using a modified Boltzmann energy distribution of the nuclear particles in conjunction with the evaporation theory and allowing for the recoil of the compound nucleus. In the case of a lithium target, however, the forward peaks of all energy groups observed seem to be too narrow (about 30° at half maximum) to be explained by a spherically symmetric neutron distribution in the center of mass system.

[1] R. B. Roberts and P. H. Abelson, Phys. Rev. 72, 76 (1947).

J5. Magnetic Analysis of Disintegration Products. W. W. Buechner, R. J. Van de Graaff, E. N. Strait, C. G. Stergiopoulos, and A. Sperduto, *Massachusetts Institute of Technology.*—An annular magnet of the Cockcroft type[1] has been constructed and employed to investigate certain reactions produced by protons and deuterons from an electrostatic accelerator. The apparatus is used to study particles emitted at 90° to the incident beam. The region of uniform magnetic field is 70 cm in diameter and 5 cm wide. The field strength is determined by a null method, natural alpha-particle groups being used for calibration. When the incident protons or deuterons are elastically scattered by thin gold foils, a sharp peak is obtained on the Eastman NTA plates used for detection, thus providing a precise measure of the voltage of the accelerator. Bombardment of thin targets of the light elements yields sharp peaks of protons and alpha-particles, groups differing in energy by one percent being clearly resolved. When somewhat thicker targets are used, the peaks broaden, the breadth affording a measure of the target thickness so that absolute thin-target cross sections may be obtained. This work was supported in part by the Office of Naval Research.

[1] Cockcroft, J. Sci. Inst. 10, 71 (1933).

J6. Energy Relations in the $Be^9(d,\alpha)Li^7$ Reaction. E. N. Strait, C. G. Stergiopoulos, A. Sperduto, and W. W. Buechner, *Massachusetts Institute of Technology.*—The analyzing magnet described in the preceding abstract has been used to study the alpha-particles from the $Be^9(d,\alpha)Li^7$ reaction. The energy of the incident deuterons was adjusted to a value (1.5 Mev) such that the alpha-particles had an energy of about 5.2 Mev. This made it possible to compare their deflection directly with that of the 5.30 Mev group from polonium. The two alpha-groups, corresponding to the formation of Li^7 in the ground and an excited level appear on the same photographic plate as the polonium group, making possible a (direct) measure of the energy difference between these two levels. This is found to be 490±10 kev, in good agreement with the results of Graves.[1] The protons from $Be^9(d,p)Be^{10}$ also appear on this plate. Measurements are

in progress using the same procedure on the protons from $Li^6(d,p)Li^7$. This work was supported in part by the Office of Naval Research.

[1] E. R. Graves, Phys. Rev. **57**, 855 (1940).

J7. Energy and Angle Variation of $Li^6(d,\alpha)\alpha$. N. P. HEYDENBURG, C. M. HUDSON,* D. R. INGLIS,† AND W. D. WHITEHEAD, JR., *Department of Terrestrial Magnetism.*—The yield curve of the reaction $Li^6(d,\alpha)\alpha$ is observed to have a sharp maximum at $\frac{3}{4}$ Mev, followed by a broad minimum before rising rapidly between 3 and 3.5 Mev, the highest bombarding energy employed. The angular distribution may be expressed in the form $1+A\cos^2\theta+B\cos^4\theta$. The coefficient A rises from a low value at $\frac{3}{4}$ Mev to a maximum slightly above unity at 2 Mev, then drops to $\frac{3}{4}$ at 3 Mev. The $\cos^4$ term is absent up to 1.5 Mev and makes a small positive contribution at higher bombarding energies.

* Office of the Chief of Ordnance, War Department.
† Johns Hopkins University.

J8. Theory of the Lithium-Two-Alpha Reactions. D. R. INGLIS, *The Johns Hopkins University.*—Recent measurements[1] of the angular distribution of the reaction $Li^7(p,\alpha)\alpha$ show that the intensity varies with angle as $1+A\cos^2\theta+B\cos^4\theta$. The odd parity of Li^7 and the even alphas permit only odd protons. The earlier treatment[2] of entering p-waves which accounts for the term in $\cos^2\theta$ is extended to include entering f-waves and yields a formula for B containing the same resonance denominator as does A. A fit with experiment is obtained with certain matrix elements treated as arbitrary parameters. The p-wave entering at low energies permits assymmetry, but a node in the numerator of A due to fortuitous properties of the compound states brings about symmetry at the lowest energy observed. In the reaction $Li^6(d,\alpha)\alpha$ the asymmetry disappears at low energy in a more natural way, because of the relative impenetrability of the barrier of the even Li^6 nucleus for d as compared with s waves. For a similar reason in $\cos^4\theta$ enters with a higher power of the relative penetrability in the Li^6 reaction than it does in the Li^7 reaction (and it is, indeed, observed[3] to be much less prominent in the former).

[1] Heydenburg, Hudson, Inglis, and Whitehead, Phys. Rev. **73**, 216 (1948).
[2] Critchfield and Teller, Phys. Rev. **65**, 10 (1941).
[3] Preceding abstract.

J9. Deuteron Bombardment of Boron and Fluorine*. E. L. HUDSPETH AND C. P. SWANN, *Bartol Research Foundation.*—The yield of gamma-rays from boron and from fluorine has been observed as a function of the energy of the bombarding deuterons. The deuteron energy was varied from about 300 to 1200 kev. The yield of gamma-rays from each element rises smoothly, with no indication of any pronounced resonances which cannot be ascribed to carbon contamination. A more thorough investigation is proceeding. The yield of protons from the bombardment by deuterons of a MnF_2 target has also been measured. The beta-ray activity induced in the target through the formation of F^{20} was observed, and this activity is proportional to the proton yield. It was found that the cross section for the reaction at 1.3 Mev is $(1.2\pm0.6)\times10^{-26}$ cm^2; this value was obtained by using a target of about 20-kilovolt thickness. The cross section is about one-third of this value at 900 kilovolts and approximately three times this value at 1.6 Mev. These data are also being extended.

* Assisted by the Office of Naval Research.

J10. Resonances in the Disintegration of Carbon by Deuterons.* T. W. BONNER, J. E. EVANS, J. C. HARRIS, AND G. C. PHILLIPS, *Rice Institute.*—Observations were made on the number of neutrons, gamma-rays, and radioactive N^{13} atoms formed when carbon is bombarded by fast deuterons. The deuterons were detected by recoil protons in a proportional counter. Neutrons were counted which proceeded in the same direction as the deuterons. Resonances at 910 and 1290 kev were obtained in the yield of gamma-radiation, neutrons, and radioactive N^{13}. A pronounced resonance at 1140 kev was observed for gamma-radiation and radioactive N^{13}, but there was only a slight indication of this resonance for neutrons in the forward direction. Since the yield of N^{13} is a measure of the total number of neutrons, this shows that the intensity of neutrons is asymmetrical. Experiments show that the resonance for gamma-radiation at 1417 kev is slightly assymetrical and its half-width is 7 kev. Studies were made on the yield of neutrons in the forward direction in the neighborhood of 1417 kev, but no evidence was found for a resonance.

* This work was supported by the Office of Naval Research.

FRIDAY MORNING AT 9:30

Hall of Government, Room 102

(R. J. SEEGER presiding)

Fluid Dynamics and Ultrasonics

K1. Effect of Length of Capillary on Capillary Rise of Polar Liquids. GEORGE ANTONOFF, *Fordham University.*—Capillary rise is sometimes affected by the length of capillary above meniscus in it. For example, in an aqueous layer benzene-water capillary rise increases with the length of the tube until a kind of saturation is reached. The true value is obtained from the author's law,

$$\gamma_{12}=\gamma_1-\gamma_2$$

where γ_{12} is the interfacial tension, γ_1 is the S. T. (Surface

Tension) of the benzene layer, and γ_2 is S. T. of aqueous layer, where the difficulty arises. Its value can be calculated as follows:

$$\gamma_2 = \gamma_1 - \gamma_{12}.$$

The capillary rise with no or little tube above gives lower values. Above a certain length it gives higher values. Thus, other than Laplacean forces operate, and their range is measured in cm. Glass below the meniscus pulls downwards. That above pulls upwards. The value of S. T. is in between and cannot be computed from capillary rise. These effects are connected with the polar character of substances used.

K2. Intensity as a Factor in Precision Measurements in Ultrasonics. J. A. FITZPATRICK, THOMAS KANKOVSKY, AND WILLIAM J. THALER, *Catholic University of America*,* (*Introduced by J. C. Hubbard*).—E. Schreuer[1] has shown that exact measurements of ultrasonic velocity in liquids by means of the Hiedemann method of visibility have a dependence upon intensity which is attributed to a development of a temperature gradient in the sound wave. This implies the necessity of stating the intensity in connection with a measurement of velocity by this method. Work in progress by optical and electromechanical methods, particularly by ultrasonic interferometry, shows that intensities necessary for the latter are much less and that velocity measurements of high precision, both in liquids and gases, may be made with the ultrasonic interferometer at intensities far below any which can affect the precision of the result.

* Assisted by the Office of Naval Research.
[1] E. Schreuer, Akustische Zeits. 4, 215 (1939).

K3. Ultrasonic Velocity in Liquid Halides. ALFRED WEISSLER, *Naval Research Laboratory*.—In order to investigate further the relation between molecular structure and the velocity of sound in liquids, measurements of sound velocity in ten liquid halides at 30° were made with a 3-Mc ultrasonic interferometer. Included were the tetrachlorides of carbon, silicon, titanium, germanium, and tin, which are of interest because their molecules may be considered as approximately spherical. The velocities observed range from about 750 to 1000 meters/second. Neither the velocity nor the adiabatic compressibility varies monotonically with the atomic number of the central atom. However, the computed ratio of specific heats is practically constant for all five tetrachlorides, as expected from their similar structures and degrees of freedom. The other halides studied were those of the phosphorus-arsenic family. Of the ten liquids, silicon tetrachloride has the highest adiabatic compressibility, in agreement with its known low internal pressure.

K4. Supersonic Absorption in Resonant Liquid Column with a Free Face. JOSEPH L. HUNTER, *John Carroll University*.—When standing waves of sound occur in liquid columns, nodal (excess) pressures of zero indicate perfect reflection and zero attenuation in the liquid. Departures from this condition are a function of attenuation and reflection constants. Experimentally, a measurement of nodal pressure may be made by loading a piezoelectric crystal with a liquid column and driving it at its response frequency. The crystal serves the dual purpose of sonic generator and pressure-measuring device. This method was used by Hubbard for measuring absorption in gases and by Fox and Hunter in liquids. It has been found that great simplification occurs if (1) only critical column lengths are considered (2) a free boundary is used as the reflecting face. It may be shown that the effect of the loaded crystal on the electrical circuit is approximately that of a pure resistance connected between the leads to the crystal, and the magnitude of absorption of supersonic waves in the liquid may be readily evaluated when the magnitude of this equivalent resistance is known. Measurements in high viscosity liquids have given absorption values close to those predicted from viscosity considerations.

K5. Concentration of Ultrasonic Beams by Curved Reflectors. F. E. FOX AND V. GRIFFING, *Catholic University of America*.—For the study of cavitation in liquids it is necessary to produce high intensity sound waves within the liquid, while avoiding cavitation at the sound source. With ultrasonic waves, a concave reflector can be used for this purpose. Elementary considerations indicate that 70–80 percent of the power in a plane sound wave beam of diameter D can be concentrated into a beam of diameter $d \simeq \lambda f D^{-1}$ if the focal region of a concave spherical reflector of focal length f, where the wave-length is λ. Using focal lengths 3–4 cm and sound in water with frequencies of 2–4 Mc, a gain (i.e., ratio of intensity in the focal region to that in the plane wave) of 30–60 might be expected. Experiments indicate that gains of this order of magnitude can be obtained. A horizontal beam of moderate intensity strikes the concave reflector which is so tilted that the reflected beam is approximately vertical. With the water surface $2f$ above the reflector, the radiation pressure of the beam striking the surface raises a mound of water about a millimeter high with an area about that of the sound source. As the water level is lowered, the area of the mound decreases and the height increases. When the surface approaches the focal region, the water is lifted out of the surface and thrown in a thin stream in an arc 10 to 15 cm high. At a critical level the water is ejected as a fine spray. Clouds are formed in which the droplets have radii smaller than 10^{-3} cm.

K6. Rigorous Expansions of the Acoustic Radiation Field on a Vibrating Piston in a Baffle.* PAUL M. MARCUS, *Massachusetts Institute of Technology*.—Several new expansions of the field of a vibrating piston in a baffle have been found which are useful for calculations at large values of ka ($k = 2\pi/\text{wave-length}$, a = radius of piston). These supplement the Backhaus-Stenzel expansions in spherical wave functions which converge well for $ka \leqslant 10$. New, useful recurrence relations and formulas are obtained for the Backhaus coefficients. An expansion in powers of $1/kR$ converges well at any ka for large enough kR. The first

term is the familiar asymptotic form of the field

$$[J_1(ka \sin \theta)/ka \sin \theta][\exp [ikR^1]/kR].$$

The derivation, based on the King integral, also gives the expansion in powers of $1/kR$ of any wave function expressible as a Sommerfeld-type integral. Rearrangement gives a series whose first term is Lommel's formula for Fresnel diffraction through a circular hole. Several expansions are based on Schoch's formula for the field as a cylindrical beam of sound (geometrical optics limit) plus a line integral diffraction correction which is small for large ka.

* This work has been supported in part by the Signal Corps, the Air Materiel Command, and O.N.R.

K7. A Method for the Instantaneous Measurement of Velocity and Temperature in High Speed Air Flow. DOUGLAS MARLOW, C. R. NISEWANGER, AND W. M. CADY, *Inyokern.*—Some preliminary experiments have been conducted to determine the feasibility of direcly measuring shock wave temperatures and particle velocities by means of a train of ultrasonic waves projected across the shock tube of a spark shadowgraph, normal to the direction of propagation of the shock front. The spark shadowgraph is an instrument which consists of a tube along which shock waves are propagated and which has a transparent section through which the shock may be photographed by means of the light from a synchronized high intensity spark discharge lasting about one microsecond. The wave train is generated by a 344-kc x cut quartz crystal mounted with its top surface flush with the bottom surface of the shock tube. The top surface of the latter is covered with felt to absorb the beam and prevent a standing wave pattern. Various forms of distortion of the ultrasonic wave fronts during and after the passage of the shock may be observed, from which the temperature and particle velocity may be deduced. For example, those waves which have left the crystal before the arrival of the shock are tilted and blown downstream as a group, those which are emitted during the passage of the shock over the crystal are displaced progressively farther downstream (as one proceeds away from the crystal surface) and bent, while those which are emitted after the passage of the shock remain straight and parallel to the crystal but are staggered echelon fashion as in the previous case. From measurements of the various angles and displacements involved one can find the temperature and streaming velocity.

K8. A Supersonic, Intermittent, Movable Wind Tunnel for Optical Studies.* R. LADENBURG, C. C. VAN VOORHIS, AND J. WINCKLER, *Palmer Physical Laboratory.*—A novel kind of supersonic wind tunnel will be described, which runs for times between a few tenths of a second and four seconds. It is used for shadow, schilieren, and interferometric studies. A pressure tank of 250 cubic feet, filled through a compressor line with dry air up to 150 lb./in.^{2}, discharges through a pressure-operated gate valve into a Laval nozzle, a diffuser, and a second tank connected to a high speed vacuum pump. The Reynolds number in the working section (cross section $3\times3''$) can be varied in the ratio 100:1. The Mach number of the present nozzle is 2.3, but much higher Mach numbers will be used also. The light source is a magnesium spark of about 0.2 microsecond duration which, with suitable interference filters, gives at least 100 interference fringes in the blue. The flow around two-dimensional and axially symmetric models and the density, temperature, and velocity profiles in supersonic boundary layers are to be studied by schlieren photography and by interferometry, using a Mach interferometer with 5″ glass plates. This instrument is shock free, supported in a fixed position, but the pressure tank with attached nozzle can be rolled back and forth on tracks so that the various parts of the nozzle may be investigated optically.

* This work is carried out under contract with the Office of Naval Research.

K9. Interferometric Analysis of Two-Dimensional Supersonic Flow Through Small Channels.* D. BERSHADER AND R. LADENBURG, *Princeton University.*—The study by interferometry of the expansion of air from a pressure tank into the atmosphere through a channel of rectangular cross section has been made possible by using plane parallel glass plates for a pair of opposite walls of the channel. Two such channels were used, each about one centimeter in width and two centimeters in depth, one being a divergent channel (half-angle = 4.0°), and the other a Laval nozzle for $M = 1.7$. Results obtained for the potential flow give good agreement with theory as well as with independent measurements of Mach angles on schlieren pictures and shadowgrams. Detailed density measurements have also been made on the turbulant boundary layers along the walls. From these measurements it has been possible to calculate, on the basis of certain assumptions, boundary layer profiles of temperature and velocity.

* This work was done under a contract with the Office of Naval Research.

K10. A Pneumatic Flow Type Pressure Controller. W. A. WILDHACK, *National Bureau of Standards.*—The constancy of flow through a nozzle for which the downstream pressure is less than 0.528 of the upstream pressure is used to obtain a variable, accurately controlled, reduced pressure independent of variations of the suction source. A small flow of air is drawn through a variable restriction in series with a nozzle, by a suction pump. The pressure in the line between the variable restriction and the nozzle depends only on the adjustment of the restriction and is independent of variations of suctions downstream of the nozzle, as long as they are less than 0.528 of the control pressure. The device requires a flow of only 1 l.p.m. and can be used as a pilot to operate large valves controlling the pressures in large chambers.

K11. A Linear-Resistance Flowmeter. A. S. IBERALL AND W. A. WILDHACK, *National Bureau of Standards.*—A linear-resistance flowmeter has been developed for general laboratory and instrument applications. It consists of a porous plug of fibrous material, usually glass, with a pressure-measuring device to indicate the pressure drop

across the plug, which is proportional to the flow. Since the flow is essentially laminar, the resistance occurs only because the viscosity of the fluid is metered, and it is independent of the density, except for corrections necessitated by molecular effusion at lower pressures. Thus, this type of flowmeter is useful in indicating the volume, or ambient, flow at various pressures. The correction for the effect of temperature on the viscosity of air, for example, is 0.8 per cent per °C. Performance equations based on hydrodynamic drag are found to be more valid for high porosity packs of fibrous materials than those based on the hydraulic radius concept. Formulas and charts are presented to permit design for maximum flows of 10^{-2} to 10^{3} l.p.m., with pressure differences of 10^{-2} to 10^{2} cm of water at full scale.

K12. A Hydrodynamic Problem: The Flapping Wavemaker. E. H. KENNARD, *David Taylor Model Basin.*—Waves of definite frequency can be generated by a boundary executing small displacements from a vertical plane P. The mathematical problem thus presented is interesting because the moving boundary extends in the direction of the subsidiary vertical space variable, whereas propagation occurs horizontally. In the absence of gravity, the motion of the water can be represented by a sheet of sources on P, reflected in the plane S of the free surface to preserve the boundary condition there. The water raised above S by this motion during each successive element of time can be treated as an "initial elevation" and represented in the usual way as a Fourier integral of harmonic oscillations, with reflection in P to preserve the boundary condition there. After a start from rest, the whole motion ultimately becomes periodic. If the horizontal displacement of the boundary at a depth y below the free surface is $\xi=\xi_0 f(y)\sin\omega t$, the amplitude of the waves of wavelength λ generated at a distance in deep water is $(4\pi\xi_0/\lambda)\times\int_0^\infty e^{-2\pi y/\lambda}f(y)dy$. The solution is easily modified for shallow water.

K13. Application of the Image Converter Tube as Electronic Stroboscope.* GEORGE H. MARKSTEIN, *Cornell Aeronautical Laboratory.*—In the course of work on periodical flow disturbances in flames it appeared desirable to observe the infra-red radiation of the flame gases stroboscopically. It was found that the infra-red image converter tube[1] 1P25 could be operated as a stroboscope by applying rectangular voltage pulses to one or several of the electrodes in such a way that the image was blanked except for a short part of the cycle. Apart from allowing stroboscopic observation in the infra-red, the device offers advantages over mechanical stroboscopes, owing to the absence of inertia, which enables synchronization even with phenomena which are not strictly periodical; the frequency range of operation appears to be limited only by the time constants of the associated circuits. Applications of the device to combustion studies will be shown.

* Work supported by the Bureau of Aeronautics and the Office of Naval Research.

[1] G. A. Morton and L. E. Flory, R.C.A. Rev. 7, 385 (1946).

K14. On the Calculation of Steady Diabatic Flows. B. L. HICKS, *Ballistic Research Laboratories.*—The direct problem amounts to determination of a flow pattern for given boundary conditions and distribution of heat sources q. Experience with almost uniform flows[1a] and with flows derivable from a potential function[1b] ($\rho=\bar{N}(g(N)RT)^{\frac{1}{2}}$, $\bar{N}=\nabla\varphi_N$) suggests that the inverse problem may be more generally tractable. In the direct problem q need not be restricted. In the inverse problem, the Crocco vector $\bar{W}=u\bar{i}+v\bar{j}$ must satisfy an integrability condition[1c] which, for uniplanar flow in the incompressible approximation, becomes $2(v_x-u_y)(u_x+v_y)+v(u_{xx}-u_{yy})+(v_{xx}-v_{yy})u=0$. An experimentally realized low speed flow $\bar{W}(x,y)$ can only fail to satisfy this equation where transient, viscous, or mixing phenomena are appreciable, if the specific heat of the fluid is constant. A new formulation of diabatic flow theory can then be based on (i) specification of $u(x,y)$ in an appropriate region; (ii) specification of v, v_x and v_y on appropriate (partial) boundaries of this region; (iii) solution of the hyperbolic equation for v; and (iv) computation of the $q(x,y)$ necessary to effect this flow. Radial and vortex flows can be calculated completely and will be used to illustrate some of these remarks.

[1] B. L. Hicks, (a) Phys. Rev. 73, (1948); (b) B.R.L. Rep. No. 633, May 1947; (c) Quar. App. Math. Apr. (1948).

K15. Relativistic Rankine-Hugoniot Equations. A. H. TAUB, *University of Illinois.*—In Part I of this paper the stress energy tensor and the mean velocity vector of a simple gas are expressed in terms of the Maxwell-Boltzmann distribution function. The rest density ρ^0, pressure, p, and internal energy per unit rest mass ϵ are defined in terms of variants formed from these tensor quantities. It is shown that ϵ cannot be an arbitrary function of p and ρ^0 but must satisfy a certain inequality. Thus $\epsilon=(1/\gamma-1)\times p/\rho^0$ for $\gamma>5/3$ is impossible. It is known that if ϵ is given by this relation and $\gamma>2$, then sound velocity in the medium may be greater than that of light in vacuum. This difficulty is now removed by the inequality mentioned above. In Part II of this paper the relativistic form of the Rankine-Hugoniot equations are derived and it is shown that, as a consequence of the inequality mentioned earlier, the shock wave velocity is always less than that of light in vacuum.

FRIDAY MORNING AT 10:00

East Building Lecture Room
National Bureau of Standards

(F. W. LOOMIS presiding)

Diverse Topics

L1. REAC: Direct Current Analog Computer.* H. BELOCK, E. BROMBERG, S. FIFER, U. MANFREDI, R. MCCOY, AND H. ZAGOR, *Reeves Instrument Corporation.*—REAC (Reeves Electronic Analog Computer) is an electronic analog computer employing direct current computing elements and servos for the solution of initial valued non-linear total differential equations. The basic component of the REAC is a direct current amplifier, and each standard REAC has a total of 20 direct current amplifiers consisting of seven integrating amplifiers, seven inverting amplifiers, and six summing amplifiers. The servos make it possible to carry out multiplications of variable quantities, to perform resolution of vectors, and to introduce arbitrary non-linear functions. Thus each standard REAC can solve differential equations up to the seventh order. However, several REACs can be connected together to increase the capacity of the equipment where higher order problems are involved. Solutions are recorded on a six-channel recorder providing graphical presentation of the effect of changing one or all of the parameters of the problem being solved. Insertion of problems on REAC is carried out by plugging of telephone cords to bays on the front of the cabinet so as to connect the input and output circuits of each amplifier in any desired manner. In order to permit continuously adjustable coefficients, 24 micropots with micrometer dials are provided. The over-all accuracy of REAC is limited by the resistors, capacitors, and drift in the power supplies. A REAC prototype has been in operation for over a year on Navy problems. Solutions of some differential equations will be shown.

* Developed under Contract, Office of Naval Research.

L2. High Speed X-Ray Motion Pictures.* C. M. SLACK, L. F. EHRKE, C. ZAVALES, D. DICKSON, AND R. G. YOUNG, *Westinghouse Lamp Division.*—A system has been developed capable of making up to 150 radiographs in one second. A special hot cathode tube is energized by a pulse transformer circuit to give x-ray pulses of 10 microseconds duration. An alternate excitation method is a choke charging voltage doubling circuit using a trigger tube. The short exposure time permits the use of continuously moving film without blur in the radiographs. Either the indirect method of photographing a fluorescent screen on motion picture film in a camera such as the General Radio oscilloscope camera, or the direct method using specially cut strip film passing over a revolving fluorescent drum may be used. In the latter case, the radiographs may be studied individually or may be photographed on motion picture film for projection as a movie. The system has been developed primarily for studying the burning of rocket propellants but should find wide application in medical and industrial fields.

* Supported by Bureau of Ordnance, Navy Department.

L3. A Small Generating Voltmeter and Generating Electrometer.* S. E. REYNOLDS AND E. J. WORKMAN, *New Mexico School of Mines.*—The authors describe a small, combination generating voltmeter and generating electrometer which is adaptable to many laboratory uses. Principles previously used by Workman and Holzer[1] have been employed in the construction of an instrument, one and one-half inches in diameter and five inches long. This unit contains a six-volt motor (1/10 watt), a rotating sector, and a subminiature vacuum tube, the grid of which is actuated by contact to the rotating sector. When the rotating sector is alternately exposed and covered in an electric field, the grid control circuit has a sensitivity of approximately 1/20 volt per volt per centimeter of field. The normal plate current is approximately ½ milliampere and may be ink-recorded directly. In another application, an insulated quadrant electrode is presented in close proximity to the rotating sector in which case the instrument becomes an indicating or recording electrostatic voltmeter or electrometer. In this case the grid control voltage may be of the order of one volt per volt on the electrode. Power consumption on the complete unit including amplifier is less than 2/10 watts. Applications of these instruments are discussed.

* The research described in this abstract was supported in part by the War Department Signal Corps.
[1] E. J. Workman and R. E. Holzer, "Recording generating voltmeter for lightning studies," Phys. Rev. **55**, 606(A) (1939).

L4. A Wide Range Field Control System for a Magnetic Spectrograph.* E. P. TOMLINSON, *Princeton University.*—A 20-cm radius of curvature double-focusing magnetic spectrograph of the type developed by Svartholm and Siegbahn[1] is being built. For this instrument a control system has been constructed by which the field of a large electromagnet may be set and held to better than 0.1 percent at any desired value between some 10 and 2000 gauss. The basic element of the system is a monitoring coil rotated in the field at 1800 r.p.m. by a synchronous motor. The resulting 30-cycle voltage, taken from the coil through slip rings, is compared in a potentiometer circuit with a fixed 30-cycle reference voltage. This reference voltage is generated by a permanent magnet rotating, on the same shaft with the monitor coil, inside a fixed coil. Electronic circuits then control the current of the electromagnet so that essentially a null output is maintained from the potentiometer. The final stage of the current control

circuit consists of six 6AS7 tubes in parallel, giving a maximum of 1.5 amperes. Four shunts, in addition to the tubes, give the necessary total current range of 0 to 5 amperes.

* This work was supported in part by Navy contract.
[1] N. Svartholm and K. Siegbahn, Arkiv. f. Mat., Ast. och Fysik 33, No. 21 (1946).

L5. Extremals of Impedance Elements in Wave Guide Equivalent Circuits.* ROBERT M. WHITMER, *Rensselaer Polytechnic Institute.*—Dr. J. S. Schwinger, in unpublished M.I.T. Radiation Laboratory work, has shown that by basing the analysis alternatively on the transverse electric and transverse magnetic fields, one may obtain upper and lower limits to the values of diagonal impedance elements. In the present work it is shown that, at least in some cases, the same procedure also gives limiting values of the squares of the off-diagonal elements. Unlike the case for the diagonal terms, the signs can be obtained only by numerical calculation.

* This work was done during the war, in the M.I.T. Radiation Laboratory.

L6. Dipole, Quadrupole, and Octupole Field and Search Coils Using Loops and Solenoids. M. W. GARRETT, *Swarthmore College.*—Symmetrical systems of coaxial circular loops designed for nearly uniform central magnetic field (Helmholtz, Maxwell, and McKeehan) produce ideal dipole fields at remote points, to the same approximation. As search coils measuring flux density, they respond only to the axial component of central field. Systems designed for uniform central gradient produce remote quadrupole fields, and measure as search coils the central gradient. Octupole and higher order remote fields correspond to systems producing second- and higher order central fields. Again, flux changes through these various systems measure dipole, quadrupole, or octupole moments of magnets or coils suddenly removed from the central region, while mutual inductance formulas for two such systems assume a primitive form. Systems of coaxial solenoids exhibit slightly modified properties. New types and individual solutions are proposed. For example, when all coils lie on a single sphere, application of recurrence formulas for Legendre polynomials permits calculation of new systems and correlation of known ones. New types employ coaxial solenoids or loops in odd or even number, include dipole quadrupole and octupole systems, may eliminate seven or more terms from the series expansion, and probably have analogues of cylindrical geometry. Solenoid forms are related to Brown's fluxball. Lyle's principle minimizes errors of finite cross section.

L7. The Diffraction Pattern of Electromagnetic Waves in the Planes of Apertures. C. L. ANDREWS, *General Electric Company.*—Measurements were made of the intensities of diffraction patterns in the planes of rectangular and circular apertures and in the planes of equivalent hoops and rods. Whether the apertures were in perfectly reflecting screens or in perfectly absorbing screens, the sharpest diffraction patterns were always in the planes of the apertures themselves. The use of equivalent hoops and rods leads to the alternate explanation of diffraction as a combination of a geometrically propagated wave with wavelets from the edges of the apertures. This treatment of diffraction as an edge effect provides the simplest means of explaining the diffraction pattern in the plane of the screen as well as behind and in front of the screen.

L8. Electrical Activity as Related to Thunderstorm Cell Growth. E. J. WORKMAN AND S. E. REYNOLDS,* *New Mexico School of Mines.*—The internal structure of a series of thunderstorms, which occurred near Albuquerque, New Mexico, during the summer of 1947, was observed by 3-cm radar. The initial appearance, subsequent growth of the radar echo-producing centers, and the time sequences involved in their development were related to the electrical activity of the storm as indicated by potential gradient change recorders. Data on twelve storm cell studies fit into a consistent pattern. The top of the earliest radar return occurred at about the 22,000 foot level (−10°C isotherm). The subsequent upward growth of the radar return was at the average rate of 850 feet per minute with a range of 450 to 1600 feet per minute. After reaching a height of approximately 31,000 feet (−28°C isotherm) the top of the radar return descended at a rate approximately equal to the rate of ascent. The initiation of electrical activity was nearly synchronous with the maximum height of the return producing area. The electrical activity increased with the descent of the top of the radar picture. In general, the electrical activity ceased when the top of the cell had lowered to approximately 24,000 feet or to about the −13°C isotherm.

* Supported by War Department Signal Corps.

L9. The Source of the Solar Magnetic Field. JAMES W. FOLLIN, JR., *Institute for Advanced Study and Princeton University.*—Recent work of Elsasser[1] has shown that the fluid motion strongly couples the various magnetic modes of a conducting sphere. The reverse coupling, required to form a regenerative system, is not as simple. It is proposed that this coupling results from the Hall effect. The resultant differential equations are non-linear and have non-zero equilibrium solutions, at least one of which is stable. In particular there is an axially symmetric solution which is stable against symmetric perturbation, but its stability against tilting of the dipole axis has not been determined. The sign of the field is determined indirectly from the current carriers (electrons) and appears to have the right magnitude and direction. The energy required to maintain the current distribution generating the field is derived from the variation of angular velocity with radius and latitude. Schwarzschild[2] has shown recently that this velocity distribution is a result of the additional energy flow caused by the effect of centrifugal force on density. Hence, this mechanism may be adequate to explain the solar magnetic field.

[1] W. M. Elsasser, Phys. Rev. **69**, 106 (1946); **70**, 202 (1946); and **72**, 821 (1947).
[2] Schwarzschild, Astrophys. J. **106**, 427 (1947).

L10. Cathode Spark Velocities in $CuSO_4$ Solutions. HUGH F. HENRY, *University of Georgia.*—The velocity of

the cathode spark produced in $CuSO_4$ solutions under application of impulsive potentials of 25 kv and 30 kv has been investigated for interelectrode gaps of 10 mm to 80 mm and for solution concentrations between 0.0020*N* and 0.0600*N*. The method used has been previously described for anode spark velocity measurements.[1] Velocities of 100–500 m/sec. have been determined. The average value for 25 kv is 235 m/sec. while the average for 30 kv is 190 m/sec. Empirically, the results indicate that the spark velocity is inversely proportional to the square root of the interelectrode gap but is directly proportional to some function of the solution normality. The average potential existing across the electrodes when the spark ceases its extension into the liquid was computed to be 15.6 kv. This value is close to that obtained for the anode spark under similar conditions.[2]

[1] H. F. Henry, Phys. Rev. **69**, 693 (1946).
[2] H. F. Henry, Phys. Rev. **72**, 184 (1947).

L11. The Refractive Index of Several Hydrocarbons in the Near Ultraviolet Wave-Length Region. JAMES L. LAUER,* *University of Pennsylvania.*—Index of refraction measurements were carried out with twenty-one liquid hydrocarbons, paraffinic, naphthenic, olefinic, and aromatic, in their respective transparent regions between 220 and 420 millimicrons, both at 20° and at 25°C, to an average accuracy and precision of ±0.0002 in refractive index. The data for each compound were fitted to an empirical equation relating frequency and index and from these the constants in the Sellmeier-Drude equation were calculated wherever possible. Interesting variations in these constants were observed for compounds of related structures. The instrument used for the measurements was the same as the one described in an earlier article.[1]

* Present address: Sun Oil Company, Norwood, Pennsylvania.
[1] James L. Lauer and P. H. Miller, Jr., J. Opt. Soc. Am. **37**, 664–668 (1947).

FRIDAY MORNING AT 9:45

Department of Interior Auditorium

(J. R. OPPENHEIMER presiding)

Symposium on Radiofrequency and Microwave Spectroscopy

M1. Outline of the Topics of the Symposium. K. K. DARROW, *Bell Telephone Laboratories.* (40 min.)

M2. Fine Structure of the Hydrogen Atom by a Microwave Method. W. E. LAMB, *Columbia University.* (35 min.)

M3. Intrinsic Magnetic Moment of the Electron. P. KUSCH, *Columbia University.* (35 min.)

M4. Hyperfine Structure of Hydrogen and Deuterium. JOHN NAFE, *Columbia University.* (30 min.)

FRIDAY AFTERNOON AT 2:15

Department of Interior Auditorium

(I. I. RABI presiding)

Continuation of the Symposium on Radiofrequency Spectroscopy

N1. Molecular Beam Experiments with Chlorine. J. R. ZACHARIAS, *Massachusetts Institute of Technology.* (30 min.)

N2. A High-Precision Determination of the Ratio of the Nuclear Magnetic Moments of Proton and Neutron. HANS STAUB, *Stanford University.* (30 min.)

N3. The Structure of Nuclear Resonance Absorption Lines in Crystals. R. V. POUND, *Harvard University.* (30 min.)

N4. Nuclear Magnetic Resonance Experiments at the Massachusetts Institute of Technology. FRANCIS BITTER, *Massachusetts Institute of Technology.* (30 min.)

N5. Nuclear Magnetic Moments of Hydrogen 3 and Helium 3. H. L. ANDERSON, *Argonne National Laboratory.* (20 min.)

FRIDAY AFTERNOON AT 2:15

Lisner Auditorium

(L. R. HAFSTAD presiding)

Reactions of Transmutation

P1. Corrections to Range Data. R. F. HUMPHREYS AND H. T. MOTZ, *Yale University.**—The interpretation of the ranges of particles emitted in an induced nuclear reaction has been considered in some detail by Livingston and Bethe.[1] They have calculated corrections due to target thickness, angle spread (for 90° observation), and range straggling that must be applied to observed extrapolated ranges to obtain mean ranges and energies. In the present work there is added to these corrections the effects of primary beam inhomogeneity, the level sensitivity of the proportional counter, and the variation of electrical counter depth. It is shown that the common practice of "peaking" a counter may introduce an appreciable shift of the extrapolated ranges caused both by shift in counter depth and by change in the observed group shape. The width of observed groups may be altered considerably by the counting level as well as by the beam inhomogeneity. To a good approximation these effects are predictable. They are shown to be range dependent and vary from reaction to reaction. Their relative magnitudes for both 90° and 0° observation are discussed.

* Assisted by the Office of Naval Research.
[1] Livingston and Bethe, Rev. Mod. Phys. 9, 245 (1937).

P2. The $Na^{23}(\alpha p)Mg^{26}$ Reaction. H. T. MOTZ AND R. E. HUMPHREYS, *Yale University.*—The corrections discussed in the above abstract have been applied to the $Na^{23}(\alpha p)Mg^{26}$ reaction for 0° observation. Thin sodium targets have been bombarded with 7-Mev alpha-particles from the cyclotron. Four groups were observed, the second of which is only barely resolved from the ground state and has not been previously reported. The beam energy and inhomogeneity has been measured by a proportional counter calibrated with ThC′ alphas. The extrapolated ranges of the proton groups have been corrected for the effect of beam inhomogeneity, angle spread, range straggling, counter "peaking," and counter depth. The corrections are of the magnitude of 5 cm for the 88 cm end group. The Q values obtained are 1.44, 1.12, -0.30, and -1.3 Mev. Gamma-ray absorption measurements[1] are in agreement with the transition from the third excited level. The ground state Q differs by 0.5 Mev from the value reported in early work, but is consistent with the reactions $Mg^{25}(d\alpha)Na^{23}$ and $Mg^{25}(dp)Mg^{26}$ studied in this laboratory. Using the Na^{22} mass reported by this laboratory[2] a new Mg^{26} mass is found to be 25.99133 ± 0.0003 Mu.

* Assisted by the Office of Naval Research.
[1] David E. Alburger, Bull. Am. Phys. Soc. 23, 9 (1948).
[2] Elder, Motz, and Davison, Phys. Rev. 71, 917 (1947).

P3. The $Al^{27}(dn)$ Reaction. R. A. PECK, JR., *Yale University.*—A thin aluminum target has been bombarded with 3.6-Mev deuterons and the energy distribution of the evolved neutrons studied, following a conventional microphotographic procedure.

P4. Energy Levels of Al 28 and Mg 25. E. POLLARD, V. L. SAILOR, AND L. D. WYLY, *Yale University.**—Al 28 can be formed by the dp reaction on Al 27. Attempts to resolve the proton structure into groups in the past have been unsuccessful.[1] This indicates an unusually close level spacing. Recent work by Seagondollar and Barschall indicates that neutron scattering by Al 27 shows fluctuations in cross section which correspond to levels in Al 28 about 70 kv apart. These are at an excitation of 7 Mev. Observation of protons from a thin layer of Al bombarded by deuterons shows the presence of 20 levels between 0 and 6.5-Mev excitation. These levels occur in five fairly definite groups, one near the ground state, which appears to be either a doublet or a triplet, and each of the others at approximately 1.3-Mev separation. The separation of the individual levels, as far as they are at present resolved, is approximately 250 kv. This is definitely less than usually observed. The maximum Q value for the above reaction is 5.64 Mev. Alpha-particles occurring in three groups of Q values 7.05, 6.38, and 5.70 Mev are observed corresponding to the ground state and two excited states of Mg 25. Additional group structure may be present.

* Assisted by the Office of Naval Research.
[1] H. L. Schultz, W. L. Davidson, and L. Ott, Phys. Rev. 58, 1043 (1940).

P5. Recent Results of Investigation of Reaction $S(dp)$. PERRY W. DAVISON, *Yale University.**—Further investigation of the proton groups from the deuteron bombardment of sulphur has disclosed the presence of a low intensity long range group with a Q of 8.8 ± 0.1 Mev. It is believed that this group corresponds to the ground state of S^{34} from the reaction $S^{33}(dp)S^{34}$. However, this assignment is not definite being based on this group's intensity relative to what is thought to be the ground state group of S^{33}, $Q=6.48$ Mev. This ratio of intensities is about 1:100 and the relative concentrations of S^{33} and S^{33} is 1:130. Assuming this assignment the following mass differences, in mass units, are obtained: $S^{33}-S^{32}$, 0.99965 ±0.00005; $S^{34}-S^{33}$, 0.9972 ± 0.0001; $S^{34}-S^{32}$, 1.9969 ±0.0002. Four of the groups previously reported and assigned to S^{33} have been found to be double. This may possibly be caused by overlapping of the S^{33} and S^{36} patterns. The definite assignment as to isotope in this study will have to wait until separated isotopes are available.

* Assisted by the Office of Naval Research.

P6. Measurement of Short Range Nuclear Recoils from Disintegrations of the Light Elements. S. K. ALLISON,

H. V. ARGO, W. R. ARNOLD, L. DEL ROSARIO, H. A. WILCOX, AND C. N. YANG, *University of Chicago.*—An energy selection of the disintegration particles from beryllium and deuterium (D_2O ice) targets under 200–400 kv proton and deuteron bombardment has been accomplished with a cylindrical electrostatic deflector. The particles emerging from the deflector are detected by an Allen electron multiplier tube.* The absence of any foil or window between the target and the detector makes is possible to observe all particles with energies below an upper limit zW_{max} where z is the number of electronic charges on the fragment and W_{max} is an upper limit defined essentially by the geometry of the deflector and the high voltage it will tolerate. In our work W_{max} is close to 1 Mev. From the reactions $Be^9(p,\alpha)Li^6$ and $Be^9(p,d)Be^8$ one observes scattered protons, disintegration α's and d's and the lithium particles, the latter appearing in three states of ionization. Unfortunately, in the present state of our experiments interference from the scattered protons prevents observation of the α's from Be^8. Scattered deuterons, He^3 and H^3 particles from the (d,d) reactions are observed. The He^3 particles indicate a provisional Q of 3.35 ± 0.05 Mev for $D(d,n)He^3$, agreeing with Bonner's 1941 value** of 3.31 ± 0.03 Mev obtained from the ranges of protons recoiling from the neutrons. Experiments are being continued.

* The preparation of electron multiplier tubes for these experiments has been accomplished with the aid of funds from the Office of Naval Research.
** T. W. Bonnner, Phys. Rev. **59**, 237 (1941).

P7. Threshold and Resonances in the $C^{14}(pn)$ Reaction.* W. E. SHOUPP AND B. JENNINGS, *Westinghouse Research Laboratories.*—The threshold energy required to induce the (pn) reaction in C^{14} has been measured to be $E_t=.662\pm.003$ Mev. This reaction is the inverse of the $N^{14}(np)$ process studied by Hughes and Eggler[1] and their observed reaction energy $Q_{np}=.597\pm.009$ Mev may be compared[2] with the negative of the reaction energy $Q_{pn}=-.617\pm.002$ Mev observed here. The errors assigned do not include errors in the absolute voltage scale that may amount to as much as 1 percent. Two resonances in the process have also been observed at proton energies of 1.135 and $1.28\pm.004$ Mev respectively. These energy levels of the compound nucleus N^{15} may be correlated with the two lowest states previously observed in the $N^{14}(np)$ reactions.[3,4]

* This work performed under contract with Office of Naval Research.
[1] Hughes and Eggler, Bull. Am. Phys. Soc. **23**, 10 (1947).
[2] Stephens, Rev. Sci. Inst., **19**, 22 (1947).
[3] Barshall and Battat, Phys. Rev. **70**, 245 (1946).
[4] Huber and Stebler, Phys. Rev. **73**, 89 (1948).

P8. The $N^{14}(n,p)$ Reaction and the Proton Range-Energy Curve. W. FRANZEN, I. C. CORNOG AND W. E. STEPHENS, *University of Pennsylvania.*—The range of protons emitted in the slow neutron disintegration of nitrogen has been measured in a cloud-chamber to be 1.00 cm of air, in agreement with other observers. The energy of this proton (561 kev as deduced from the extrapolated end-point of the C^{14} beta-spectrum and the n-H mass difference) establishes a point on the proton range-energy curve. This point agrees well with Bethe's 1937 curve,[1] but deviates considerably from his later curve.[2] It is pointed out that other points can be established on the proton range-energy curve in this region by data on reaction cycles involving (a) other slow neutron (n,p) reactions [$He^3(n,p)$, $B^{10}(n,p)$, $Cl^{35}(n,p)$, $Sc^{45}(n,p)$] and the extrapolated end-points of the beta-spectra of the product nuclei; (b) protons emitted in $D^2(\gamma,n)$ and the energy of the gamma-ray (ThC'', Na^{24}); (c) H^3 nuclei emitted in $He^3(n,p)H^3$ and $Li^6(n,\alpha)H^3$ (in these cases proton ranges can be computed from the H^3 ranges with small error). Existing data on these types of experiments will be compared with published range-energy curves to point out agreements, discrepancies and possibilities for further measurements.

[1] Livingston and Bethe, Rev. Mod. Phys. **9**, 268 (1937).
[2] H. A. Bethe, Phys. Rev. **53**, 313 (1938).

P9. Thin Target (α,n) Cross Sections of Be, Mg, and Al.* I. HALPERN,** *Los Alamos Scientific Laboratory.*—The (α,n) cross sections for beryllium, magnesium, and aluminum were measured as a function of alpha-energy up to the full energy of polonium alphas. The cross sections were determined by counting the neutrons released in the reactions in a graphite block with a slow-neutron counter. The energy response of the counting apparatus was reasonably "flat." The disintegration chamber was of spherical geometry with the source at the center. Energies of alphas incident on the surrounding target were determined by the pressure of the stopping gas in the chamber. The target and source thicknesses were such that the energy resolution was of the order of 10 percent. The lowest resonance in beryllium occurs at 1.6 Mev. The cross section at the peak is .13 barns and rises to .4 barns at 5 Mev. The aluminum and magnesium cross sections are smaller by a factor of about twenty, and no resonances can be identified with certainty.

* The information contained herein will appear in Division V of the National Nuclear Energy Series (Manhattan Project Technical Section) as part of the contribution of the Los Alamos Laboratory.
** Now at Massachusetts Institute of Technology.

FRIDAY AFTERNOON AT 2:15

Hall of Government, Room 102

(H. A. BOORSE presiding)

Cryogenics

Q1. Superconducting Noise and Rectification. DONALD H. ANDREWS, *Johns Hopkins University.**—Using a superconducting bolometer of CbN, measurements have been made of the background noise for 18 values of the current between 0 and 42 ma. Temperature was varied slowly over the transition range between 15° and 16°K and simultane-

ous tracings made with two recording potentiometers of the d.c. resistance of the bolometer and of the amplified and rectified noise potential. For low current the noise was greatest in the superconducting state and for high current in the normal state. As temperature varied, there were many peaks of noise, the pattern varying strikingly with current. At high currents the peaks were associated with breaks in the d.c. resistance curve. The pattern of rectification at radio frequency showed similar variations with different values of imposed d.c. The magnitude of rectified signal was greatest for r.-f. between 0.2 and 1.2 mc. and between 50 and 110 mc. Rectification was at a maximum for r.-f. modulated between 300 and 700 c.p.s. and fell off sharply above 1200 c.p.s. Reversing the direction of d.c. changed both the magnitude and temperature pattern of rectification.

* This research was carried out under a basic research contract with the Physics Division, Office of Naval Research, U. S. Navy.

Q2. A Recent Study of the Infra-Red Sensitivity of Superconducting Bolometers.* NELSON FUSON, *Johns Hopkins University.*—25 columbium nitride superconducting bolometers have been studied for sensitivity and noise characteristics. These bolometers were irradiated with a wide band of 360 c.p.s. square wave modulated, infrared radiation of about $\frac{1}{10}$ microwatt mm² intensity. The bolometer response was amplified by a matching input transformer and wide band amplifier such that the combined gain was 5×10^6. Time constants ranging from 0.8 to 17.0 milliseconds were measured for the last 12 bolometers studied. The minimum detectable power of these latter bolometers range from 0.3 to 300×10^{-10} watt when calculated under the reference conditions suggested by Jones.** Comparisons are given between these superconducting bolometers and other infra-red detectors described in the literature.

* This work has been supported by the Rockfeller Research Foundation.
** R. Clark Jones, J. Opt. Soc. Am., 37, 879 (1947).

Q3. Surface Impedance of Tin at 24000 mc/sec.* E. MAXWELL, P. M. MARCUS, AND J. C. SLATER, *M.I.T.*—The surface resistance of white tin has been measured at 24000 mc/sec. from 300°K at 4°K and in the superconducting state from 4° to 2°K. It is found, in agreement with other experimenters[1] that the surface resistance approaches an asymptotic value at low temperatures independent of the d.c. resistivity. At 4°K the apparent a.c. resistivity is 60 times the d.c. value. The general form of the variation roughly follows the (unpublished) theory[2] of E. H. Sondheimer and A. E. H. Reuter of Cambridge. By fitting the experimental data to the theoretical curve one can calculate an approximate value for the number of free electrons per atom. We find a value of 0.2. The theory can be extended to the superconducting case by adding another term for the super-current. It is then possible to obtain the variation with temperature of the static penetration depth λ, of the superconductor, by making assumptions about the change in the number of normal electrons below the transition temperature. The curve obtained agrees approximately with other determinations and we find a value of 7×10^{-6} at 2°K.

* This work has been supported in part by the Signal Corps, Air Materiel Command and O.N.R.
[1] London, H., Proc. Royal Soc., A176, 522 (1940); Pippard, A.B., Proc. Roy. Soc. A191, 371 (1947); Garrison, J.B., Ph.D. thesis, M.I.T., 1947.
[2] Private communication to Prof. J. C. Slater.

Q4. On Temperature Dependence of Penetration Depth in Superconductors. JULES DE LAUNAY AND M. C. STEELE, *Naval Research Laboratory.*—Using the Gorter-Casimir thermodynamic theory of superconductivity, the form of the Sommerfeld relation for the specific heat of electrons, the form of the acceleration theory for the penetration depth, λ, and the parabola relationship for the threshold magnetic fields, it is found that the variation of λ with temperature T is given by $\lambda/\lambda_0=[1-(T/T_c)^6]^{-\frac{1}{2}}$, where λ_0 is the penetration depth at 0°K, and T_c is the transition temperature for no applied magnetic field. Comparison with experiments on mercury and tin shows good agreement. Absolute values for the penetration depth of these elements are calculated from the experimental results by using the derived equation.

Q5. De Haas-van Alphen Effect in Zinc. L. ONSAGER AND J. E. ROBINSON, *Yale University.*—Blackman's theory[1,2] of the de Haas-van Alphen Effect is applied to data obtained by S. G. Sydoriak[3] for Zn at 4.2°K. Agreement with theory for fields up to 3 kilogauss is good for the spacing of the oscillations of the magnetic moment, less certain for the envelope shape. Data for higher fields is incomplete. The data for Zn can be accounted for in terms of one zone of hexagonal symmetry containing about 8×10^{-6} electrons per atom, these electrons having a chemical potential $E_0\sim.02$ ev, longitudinal effective mass $m_{||}\sim20m_0$, and transverse effective mass $m_\perp\sim.01m_0$. As implicitly required for the application of Blackman's theory, the computed specific heat of the de Haas-van Alphen zone is small compared to the measured electronic specific heat.

[1] M. Blackman, Proc. Roy. Soc. (A), 166, 1 (1938).
[2] D. Shoenberg, Proc. Roy. Soc. (A), 170, 341 (1939).
[3] S. G. Sydoriak, Bull. Am. Phys. Soc., 23, No. 2, p. 15.

Q6. Characteristics of Liquid Air as a Low Temperature Bath. LESTER I. BOCKSTAHLER AND HARMON PLUMB, *Northwestern University.*—Baths of liquid air, pure oxygen, and commercial nitrogen were studied under the usual laboratory operating conditions. The temperature and oxygen content of each bath was determined at regular time intervals as the liquid evaporated (a) freely under atmospheric pressure, (b) rapidly at reduced pressure, (c) rapidly upon the introduction of an immersion heater. Temperatures were read by means of a platinum-resistance thermometer. The percent oxygen content was computed from density measurements made by the usual Jolly balance method—weighing an aluminum cylinder in air, water and in the liquid in turn. The comparative behavior of each liquid sample is shown by time-temperature graphs.

Freshly prepared liquid air may vary as much as twenty percent in oxygen content depending on the method of liquefaction. Results of the oxygen-nitrogen composition are in good agreement with the values found by Dodge and Dunbar[1] using varying mixtures of pure oxygen and nitrogen.

[1] J. Am. Chem. Soc. **49**, 591 (1927).

Q7. The Effect of Relaxation on the Theory of Second Sound in Helium II. WILLIAM BAND AND LOTHAR MEYER, *University of Chicago.*—Following the idea that propagation of second sound implies a lack of internal equilibrium, the equations for the two-velocity field model of liquid helium II[2] are generalized. Expressions follow for $V_{s\infty}$, $V_{n\infty}$ and V_{s0}, V_{n0}, respectively the velocities of propagation of second sound and normal sound at infinite frequency (no relaxation) and zero frequency (complete thermal equilibrium or full relaxation). At zero frequency the second sound reduces to thermal diffusion (V_{s0} imaginary). Normal sound undergoes a sharp Einstein dispersion and absorption at the lambda temperature (for generally used frequencies) in agreement with attenuation measurements.[3] The theory is used to compute σ the fraction of normal particles from thermodynamic and second sound velocity data,[4] and the energy per normal particle is obtained from σ and the experimental data on total heat content.

[1] W. Band and L. Meyer, Phys. Rev. **73**, 226 (1948).
[2] L. D. Landau, J. Phys. U.S.S.R. **5**, 71 (1941); **11**, 91 (1947); L. Tisza, Phys. Rev. **72**, 838 (1947).
[3] J. R. Pellam and C. F. Squire, Phys. Rev. **72**, 1245 (1947).
[4] V. P. Peshkov, J. Phys. U.S.S.R. **8**, 381 (1944); **10**, 389 (1946); C. T. Lane, H. Fairbank and W. Fairbank, Phys. Rev. **71**, 9 (1947).

Q8. Relaxation and Heat Conductivity in Liquid Helium II. LOTHAR MEYER AND WILLIAM BAND, *University of Chicago.*—The equation for thermal diffusion derived above[1] agrees with the relaxation equation used previously[2] if the second sound velocity is corrected to zero frequency. The relaxation time τ is calculated to a higher accuracy. The peculiar property of the heat current in being proportional to the cube root of the temperature gradient can be phenomenologically reduced to the relation $u_s^2\tau_s = J$, where u_s is the velocity of the superfluid balancing the mass flow of normal particles transporting the energy. τ_s is a relaxation time derived from τ by the conditions for frequency balance. J is a simple function of temperature only, approaching $h/m\pi$ at temperatures below 1°K. The equations lead to a qualitative understanding of the reduction of thermal conductivity by mass flow.[3]

[1] Meyer and Band: preceeding abstract.
[2] Band and Meyer, Phys. Rev. **73**, 226 (1948).
[3] Kapitza, P., J. Phys. U.S.S.R. **4**, 181 (1941).

Q9. Approximate Methods in Momentum Space. M. DRESDEN, *University of Kansas.*—A theoretical discussion of the properties of liquid He II should be based on the properties of the (non-relativistic) quantum mechanical many-body problem. Since it has been conjectured that at low temperatures there exists some kind of order in momentum space,[1] it has seemed worth while to obtain methods which will approximate the momentum wave function directly. This wave function satisfies an integral equation of the Hopf-Wiener type. It is possible using the conventional integral equation methods to obtain a sequence of functions the limit of which is the exact wave function in momentum space. Fourier inversion of the members of the sequence gives then an approximating sequence for the wave functions in coordinate space. Each member of this sequence can be expressed in terms of integrals over the potential energy function. The first approximation to this coordinate wave function, describes particles in essentially a constant field (some averaged field)—the next approximation utilizes more details of the potential energy function. Similar methods can be used to obtain the eigenvalues—in particular some information about the lowest eigenvalue and the lowest wave function can be obtained.

[1] F. London, Rev. Mod. Phys. **17**, 310 (1945).

FRIDAY AFTERNOON AT 2:30

East Building Lecture Room
National Bureau of Standards

(E. C. CRITTENDEN presiding)

Invited Papers on Basic Physical Measurements at the National Bureau of Standards

R1. Intercomparisons of the Standard Meter. L. V. JUDSON. (20 min.)
R2. Spectrum Lines of Hg 198 as Standards of Length. W. F. MEGGERS. (20 min.)
R3. The Absolute Electrical Units. F. B. SILSBEE. (20 min.)
R4. Proposed Revision of the International Temperature Scale. H. F. STIMSON. (20 min.)
R5. Radioactivity and Neutron Standards. L. F. CURTISS. (20 min.)
R6. Microwave Frequency Standards. H. LYONS. (20 min.)

SATURDAY MORNING AT 9:45

Lisner Auditorium

(W. F. G. SWANN presiding)

Mesons Natural and Artificial

S1. Production of Mesons by the 184-inch Berkeley Cyclotron. Part I. Experimental Arrangement.* EUGENE GARDNER AND C. M. G. LATTES, *University of California, Berkeley.*—We have observed tracks which we believe to be due to mesons in photographic plates placed near a target bombarded by 380 Mev alpha particles. The plates used were Ilford Nuclear Research Plates, type C.2. The identification of the particles responsible for the tracks was first made on the basis of the appearance of the tracks; they show the same type of scattering and variation of grain density with residual range found in cosmic-ray meson tracks by Lattes, Occhialini, and Powell,[1] and about two-thirds of them produce observable stars at the end of their range. For a 10-minute exposure in the cyclotron, about 50 meson tracks are found along the 3-inch edge of a photographic plate. Carbon, beryllium, copper, and uranium have been used so far as target materials, and all are found to give mesons. When a carbon target was bombarded with 300 Mev alpha particles, mesons were found but with reduced yield.

* This paper is based on work performed with the support of the Atomic Energy Commission.

[1] C. M. G. Lattes, G. P. S. Occhialini, and C. F. Powell, Nature 160, 453, 486 (1947).

S2. Production of Mesons by the 184-inch Berkeley Cyclotron. Part II. Mass Determination.* C. M. G. LATTES AND EUGENE GARDNER, *University of California, Berkeley.*—The mass of the mesons produced by the 184-inch Berkeley cyclotron has been determined by measuring the bending in the magnetic field and the range in emulsion. The radius of curvature of the trajectory is found by measuring the distance from the target to the point at which the meson enters the emulsion and the angle which the track makes with the edge of the plate. From the first 50 meson tracks measured we find a mass of 313 ± 16 electron masses. It is highly probable that these mesons are the heavy mesons described by Lattes, Occhialini, and Powell.[1] The mass determination which we have made was done with apparatus intended only for survey work, and some of the error is associated with lack of precision of location of the photographic plates. There was an aluminum foil of thickness 0.001 inch in front of the plates. It is thought that much better accuracy will be possible with better apparatus and a thinner foil.

* This paper is based on work performed with the support of the Atomic Energy Commission.

[1] C. M. G. Lattes, G. P. S. Occhialini, and C. F. Powell, Proc. Roy. Soc. (in press).

S3. Search for Photons from Stopped Mesons. ORESTE PICCIONI, *Massachusetts Institute of Technology.*—The main purpose of this research was to investigate whether the rest energy of negative (normal) mesons, captured in Fe, is released in the form of light. At the same time a check has been made on the possibility that photons are emitted together with electrons, in the decay process of positive mesons stopped in Fe. The apparatus consists of a vertical telescope for collimating a beam of penetrating particles in an iron plate (absorber). By means of anti-coincidence counters, events were selected corresponding to particles stopped in the absorber. For those events a picture was taken of a scope indicating which one of a group of counters H was discharged. The counters H were disposed at one side of the absorber, and from the picture it was possible to determine whether a photon coming from the iron was converted in a lead plate. The results rule out the assumption that one (or more) photon of energy 30 Mev (or more) accompanies the stopping of each negative meson. The same results indicate as well that the decay process of positive mesons does not involve emission of high energy photons. This is in agreement with a recent works of R. Sard and co-worker, and of B. Pontecorvo and co-worker. In the hypothesis of a neutral meson emitted in the process involving the disappearance of a negative meson, a lower limit of 10^{-10} sec. is established for the mean life of such a neutral particle, assuming that it would decay in two high energy photons.

S4. Search for Heavy Particles from Stopped Mesons.* W. Y. CHANG, *Princeton University.*—A cloud chamber of 12 inches diameter, 5 inches depth and having small dead space was constructed for studying meson absorption by nuclei. A vertical meson beam is selected by a three-fold coincident telescope, which is put above the chamber and protected against side-showers by anticoincident counters. The lower circumference of the chamber is surrounded with many anticoincident counters, so that the chamber expands only when a particle stops in the chamber or in the chamber and counter walls. Before entering the telescope the mesons pass through a lead block of 35 cm to increase the slow meson intensity. The chamber is kept in a constant-temperature room and found to work satisfactorily for days without readjustment. The operation of the chamber, the lights, camera, etc. is controlled automatically by an electronic unit. Thin iron (0.028 inch) and lead (0.018 inch) foils have been separately put inside the chamber. Our preliminary results (more than ten pictures) show no evidence of star production or emission of a single heavily ionizing particle when a meson appears to stop at a foil. The emission of a neutral particle such as a neutral meson seems, therefore, to be necessary after nuclear capture of a negative meson. The effect being studied is smaller than any one of the effects due to side-showers, absorption by the chamber and counter walls, inefficiency of the anti-coincident counters, scattering from the top of the cham-

ber, etc. These have made the experiment fairly difficult. Improvements are being made and further results will be reported.

* This work was supported in part by Office of Naval Research.

S5. The Time Distribution of Decay Electrons from Mesons Stopped in Magnesium at 3500 m Altitude.* R. D. SARD AND A. H. BENADE, *Washington University.*—Two sets of G-M tubes, above (*I*) and below (*II*) a 7.6 cm Mg block respond respectively to the incident meson and the decay electron. The circuit[1] records delayed coincidences of the pulses from *I* and *II* in ten contiguous channels ranging from 0.5 to 6.5 μsec. Beneath *II* is a counter tray, *C*, separated from it by a Pb slab thick enough to stop any decay electron from the Mg. The circuit can be switched to respond only if *C* discharges within 0.5 μsec after *I*. In this way the distributions of counter lags greater than 0.5 μsec is determined. Measurements of these lags and of decay electrons were alternated; frequent calibrations were made. There were enough spontaneous lags in the first channel to necessitate an appreciable correction to the decay data for this channel. A differential plot of the 1663 points in the later channels (1.1 to 6.5 μsec) gives a smooth curve, closely fitting that calculated assuming equal numbers of positive and negative stopped mesons, with mean lives of 2.2 and 1.0 μsec respectively.[2] A single exponential with a mean life of 1.7 μsec gives not as good a fit.

* We are indebted to the U. S. Navy for support, and to M. Schein and E. F. Fahy for permission to use the University of Chicago Laboratory at Climax, Colorado.
[1] Based on a design of M. L. Sands: B. Rossi, M. Sands, and R. D. Sard, Phys. Rev. **72**, 120 (1947).
[2] H. K. Ticho and G. E. Valley; results obtained independently and communicated at the Chicago Meeting, American Physical Society, Dec. 30, 1947.

S6. Decay of Mesons in Carbon. C. W. KISSINGER AND D. COOPER, *University of Maryland (Introduced by D. Cooper).*—A method is being used for determining the life times of positive and negative mesons in carbon. Geiger-counters in coincidence define a solid angle. Slow positive and negative mesons are separated in a magnetic field and deflected into graphite blocks placed outside the solid angle. The decay electrons are detected as they emerge from the respective graphite blocks. The time between the pulse from the meson and the pulse from the decay electron is measured on a servoscope by photographing the trace. Anticoincidence counters are used to prevent sweeping of the servoscope by mesons that are not deflected into an absorbing block. Preliminary results indicate that both positive and negative mesons decay in carbon with the ejection of an ionizing particle. These results are in agreement with the results of other experiments on the decay of negative mesons in elements of low atomic number.[1,2,3]

[1] M. Conversi, E. Pancini, and O. Piccioni, Phys. Rev. **71**, 209 (1947).
[2] H. K. Ticho and M. Schein, Phys. Rev. **73**, 81 (1948).
[3] G. E. Valley and B. Rossi, Phys. Rev. **73**, 177 (1948).

S7. On the Energy Dependence of the Positive Meson Excess.* M. H. SHAMOS, M. G. LEVY, AND I. S. LOWER, *New York University.*—The numbers of decay electrons (delayed more than 1 μsec.) from carbon and aluminum have been measured under 10 cm, 30 cm, and 50 cm, of Pb at sea level. The relative sizes of the absorbers were chosen in the ratio of the ranges of the decay electrons in the two materials so as to assure equal probability for detection. Measurements on the mean life are consistent with the value 2.15 μsec. (with a precision of ±10 percent). Under the assumption that both positive and negative mesons decay in carbon, while only the positive mesons decay in aluminum, the relative yields (after subtracting background) permit the comparison of the total number of mesons with the number of positive mesons. The results show no significant dependence upon energy (in the range ~200–800 Mev in agreement with cloud chamber results,[1] but are in agreement with a 20 percent positive excess only if negative mesons do undergo decay in aluminum, the fraction decaying (beyond 1 μsec.) being ~.30±.16. Extrapolation of this fraction to zero time, assuming the apparent mean life of negative mesons in aluminum is ~0.7 μsec.,[2] would indicate that *all negative mesons decay in aluminum.* Although the precision of this result is rather poor, it is fairly certain that some fraction of the negative mesons decay in aluminum.

* Supported by the Office of Naval Research.
[1] V. J. Hughes, Phys. Rev. **57**, 592 (1940).
[2] G. E. Valley and B. Rossi, Phys. Rev. **73**, 177 (1948).

S8. Slow Mesons in the Atmosphere.* MATTHEW SANDS, *Massachusetts Institute of Technology.*—Further measurements have been made, at altitudes between sea level and 11,000 meters, of the intensity of mesons near the end of their range. The apparatus was similar to that used previously and the results agree with those reported.[1] Measurements were made also with 7.5 cm of lead above the apparatus. The altitude variation of the counting rate was the same as that observed without lead. The same selection technique has been used with a different geometry to determine directly the differential range spectrum and the absolute intensity at sea level of mesons with ranges between zero and 30 cm of lead. The vertical intensity at sea level of mesons which stop and decay in 15 g cm^{-2} of carbon was found to be $(4.4\pm0.3)\times10^{-3}$ sec.$^{-1}$ sterad^{-1}. The intensity of mesons which penetrate 166 g cm^{-2} of lead and stop in 15 g cm^{-2} of carbon was found to be $(5.1\pm0.3)\times10^{-3}$ sec.$^{-1}$ sterad^{-1}, which value agrees with the result of Koenig.[2]

* The work reported was supported in part by the Office of Naval Research. The aircraft used was provided by the Army Air Forces.
[1] B. Rossi, M. Sands and R. F. Sard, Phys. Rev. **72**, 120 (1947).
[2] H. P. Koenig, Phys. Rev., **69**, 590 (1946).

S9. An Interpretation of Dual-Cosmic Ray Events. R. M. LANGER, *Bureau of Ships,* AND HERMAN YAGODA, *National Institute of Health.*—Three *II*-pronged events recorded in nuclear emulsions exposed at sea level cannot be attributed to nuclear evaporations of component atoms. The three events are related in that the energy and momenta of the particles producing the tracks are explicable on the transformation of heavy primary mesotrons into charged mesotrons of smaller mass. The first event is represented by a 1 Mev proton track and a meson with a recorded track length of 2170 microns having an angle between tracks of 100°. In the second event the track of a 13

Mev alpha particle and a 4.1 Mev secondary mesotron diverge at an angle of 120° and terminate in the emulsion layer. The emergent mesotron has a range of 613 microns and appears to be identical with the u-mesotrons described by the British investigators. Momenta considerations indicate a mass of 630 m_e for the incident particle. The third even is comprised of the tracks of two mesotrons of 6 and 1 Mev kinetic energy divirging at an angle of 138°. If their masses be assumed equal (200 m_e), the incident mass corresponds to 400 m_e. The spatial orientation of the events in the original AgBr-gelatin layer suggests that the incident mesotrons were probably uncharged.

S10. Emission of Radiation in the Disintegration of Mesons. DANIEL B. FEER, *Harvard University.*—When a meson of integral spin disintegrates into an electron and neutrino, the acceleration of charge should be accompanied by electromagnetic radiation. The amount of such radiation has been calculated by second-order Dirac perturbation theory for various types of coupling. In common with other second-order radiative effect calculations, the total cross section diverges logarithmically (infra-red catastrophe), so that the lifetime for this process alone cannot be calculated. The ratio of the mean radiation energy emitted to the energy available from the disintegration gives a measure of the probability of the process. For all models considered this ratio is about 0.85 $e^2/hc=0.6$ percent, and varies logarithmically with the meson mass. It is too small to be observed in the experiments designed to detect 50 Mev photons from the decay of mesons of spin one-half.

S11. Trajectories of Charged Meson Test Particles in the Similarity Geometry. BANESH HOFFMANN, *Queens College.*—With the same physical identifications of the components of the basic similarity tensor $S_{\sigma\tau}$ as in the unitary field equations of the gravitational, electromagnetic, and vector meson fields,* the geodesic-like variational principle

$$\delta\int\left\{s_{\sigma\tau}\frac{dx^\sigma}{dt}\frac{dx^\tau}{dt}\right\}^{\frac{1}{2}}dt=0 \qquad (s_{\sigma\tau}\equiv S_{\sigma\tau}/S_{00}),$$

yields the correct equations for the trajectories of charged meson test particles. The ideas behind the similarity theory reveal a close relationship between the hitherto diverse unitary theories of Weyl and Kaluza. The geometers showed that four-dimensional conformal geometry deals with conformal tensors having 6^4 components. Though not incorporating these two extra degrees of freedom, Weyl's geometry is fundamentally conformal. Kaluza's "five-dimensional" theory uses one extra degree of freedom in a projective way such that it may properly be regarded, as can Weyl's theory from a different point of view, as an embryonic form of a general conformal theory.

* B. Hoffmann, Phys. Rev. **72**, 458 (1947); *ibid.* **73**, 30 (1948).

Invited Paper

S12. Theory of Meson Production. W. HEITLER, *Dublin Institute for Advanced Studies.* (45 min.)

SATURDAY MORNING AT 9:30

Hall of Government, Room 102

(M. GOLDHABER presiding)

Artificial Radioactive Substances

T1. Double Beta Decay.* E. FIREMAN, *Princeton University.*—There exist a number of stable isobaric nuclei that differ by two in charge and may differ by several Mev in mass. The heavier should decay into the lighter with simultaneous emission of two electrons. The decay probability depends markedly upon whether or not the two electrons are accompanied by two neutrinos. No neutrinos are emitted if they obey the Majorana equation or if the interaction is composed of linear combinations of the usual interactions. Furry's calculations using Majorana wave functions have been extended to linear combinations that arise from symmetry considerations and meson theories. Isobars belonging to a triple set are the most promising for double beta decay since the middle one is near the minimum of the isobaric mass defect curve. Therefore, $_{40}Zr^{96}$ and $_{50}Sn^{124}$ were investigated with a Geiger counter coincidence arrangement. Their activity was compared with elements that are stable against all types of decay. No difference was detected. On the basis of these measurements and the assumption of two-Mev mass difference, the lifetime of $_{50}Sn^{124}$ is greater than $3\cdot10^{15}$ years. This result rules out the polar vector, axial vector, and tensor interactions with Majorana wave functions and the more important linear combinations.

* This work was supported in part by Navy contract.

T2. Measurement of Absorption Coefficients for Gamma-Rays in Various Materials.* ARTHUR L. HUGHES AND CLYDE L. COWAN, *Washington University.*—The availability in the past year of a number of radio-isotopes from the Atomic Energy Commission has permitted measurements to be made of absorption coefficients for a range of gamma-ray energies heretofore impracticable. Insofar as possible, monoenergetic gamma-sources with long half-

lives were selected which covered the energy spectrum from 0.4 to 2.8 Mev. A geometry was sought which would yield results whose accuracy was limited only by statistics and by natural background corrections. The source, absorbers of area just sufficient to completely intercept all detected gamma-rays, and G.M. tube were suspended outdoors about 25 feet above the ground. The lowest obtainable background with source present was of the order of four times natural background and was a function of the activity of the source. This was due to back scattering by the air. Sufficient data were taken at each point to reduce the statistical error to less than one percent. The following sources were used: Cr-51, Au-198, Cs-135, Sc-46, Zn-65, Co-60, Sb-124, Na-24 and Cs-134. Absorbers used were Pb, Sn, Cu, Al and C. The results, where there is good reason to believe that the gamma-rays were monoenergetic, exhibit remarkable agreement with the values predicted by Heitler.

* This work was supported in part by the Office of Naval Research.

T3. Gamma-Ray Absorption Measurements. CHARLOTTE M. DAVISSON AND ROBLEY D. EVANS, *Massachusetts Institute of Technology.*—The absorption of γ-rays in Al, Cu, Sn, Ta, and Pb has been measured in "good geometry" using the γ-rays from I^{131}, Cu^{64}, Mn^{54}, Co^{60}, An^{65}, and Na^{24}. The absorption curves of I^{131} showed the presence of a 0.65 Mev γ-ray 15 percent as abundant as the 0.367 Mev γ-ray. The absorption coefficients of Mn^{54} (0.835 Mev), Zn^{65} (1.14 Mev), Co^{60} (1.16 and 1.31 Mev), and Na^{24} (2.76 Mev separated from 1.38 Mev by coincidence counting) showed agreement within 0.5 percent to 2 percent with the absorption coefficients expected from the theories of Klein-Nishina,[1] Hulme *et al.*,[2] and Bethe and Heitler.[3] Transmissions were measured to about 0.01–0.005 with Zn^{65}, Na^{24}, Cu^{64}, and I^{131}, and to about 0.001 or lower with Mn^{54} and Co^{60}. As one check on the apparatus, absorption measurements were made with Ra γ-rays. These showed that the apparatus has excellent collimation since the results agreed both with those of other workers and with those expected theoretically.

[1] Klein and Nishina, Zs. f. Phys. **52**, 853 (1928).
[2] Hulme, McDougall, Buckingham, and Fowler, Proc. Roy. Soc. **149A**, 131 (1935).
[3] Bethe and Heitler, Proc. Roy. Soc. **146A**, 83 (1934).

T4. A Method for Measuring Short Period Activities.* A. D. SCHELBERG, M. B. SAMPSON, AND A. C. G. MITCHELL, *Indiana University.*—By photographing an oscilloscope it is possible to measure short periods which range from 0.1 second to 5 seconds. The pulses from a Geiger counter are fed into the x-axis amplifier of an oscilloscope using no sweep. A General Radio Oscillograph Recorder is used to photograph the cathode ray tube so that a record is obtained. The activated target is moved from the bombardment position to the counting position in about 0.2 second by means of a pneumatic tube. Exposure of calcium to a 23 Mev alpha-particle beam results in an activity with a half-life of 0.58 ± 0.04 second. This activity may be assigned to Ti^{43} produced by the reaction $Ca^{40}(\alpha,n)Ti^{43}$.

* Supported by Office of Naval Research.

T5. The Formation of Be^{10}. C. EGGLER, D. J. HUGHES, AND C. HUDDLESTON, *Argonne National Laboratory.*—The radioisotope Be^{10} is of great interest because its half-life is extremely long in spite of the expected allowed nature of its disintegration. As part of a program of study of this activity we have investigated methods of making Be^{10} in the pile. The formation of Be^{10} by the (n,γ) and the (n,α) reactions has already been reported.[1] Because of the small yields of these reactions it was decided to investigate the (n,p) as well. Although the latter is slightly exothermic the penetrability of the proton and the self protection of the sample for slow neutrons will make the formation of Be^{10} by the thermal neutrons extremely small. The main source of Be^{10} was expected to be the fast neutrons so some amorphous boron was irradiated near the uranium lumps in the Hanford pile. Beryllium carrier was added to the boron and then separated using the basic acetate process. The final beryllium showed an activity which did not decay and had the correct absorption curve for Be^{10}. The specific activity obtained gives a cross section for fast pile neutrons of 3 millibarns and shows no appreciable contribution from thermal neutrons.

[1] Hughes, Eggler and Huddleston, Phys. Rev. **71**, 269 (1947).

T6. The β-Spectrum of Be^{10}. D. J. HUGHES AND C. EGGLER, *Argonne National Laboratory.*—The disintegration of Be^{10} is expected to be allowed on the basis of spin difference and of comparison with the mirror nucleus C^{10}. However, its half-life of about 3×10^6 years indicates a highly forbidden disintegration. It is therefore of interest to determine if the β-distribution is of an allowed or a highly forbidden shape. Because of the great half-life and low cross section for the formation of Be^{10} (preceding abstract) it seems likely that material will not be available for a spectrometer determination of the spectrum for some time. We are measuring the spectrum, therefore, by comparison with "standard" spectra, which can be measured accurately in the spectrometer. The comparison is made both by means of the shape of β-absorption curves and by observing the β-energy distributions in a helium filled cloud chamber. Assumption of a linear decrease of intensity with absorber thickness allows a simple conversion from absorption curve to spectrum shape, and study of standard spectra (W^{185}, Au^{198}, P^{32}, Cu^{64}) shows good correlation with their known β-distributions. The β-spectrum of Be^{10} given by the absorption method is found to have the allowed shape within experimental error.

T7. A New 20-Second Activity Induced in Boron by High Energy Protons.* R. SHERR, H. R. MUETHER, AND M. G. WHITE, *Princeton University.*—When elemental boron or boron compounds such as boric acid are bombarded in a thin copper cell by 16–18-Mev protons, the resulting C^{11} radioactivity may be partially extracted as CO_2 by blowing a gas through the cell. Strong activities can be blown 40 feet in a fraction of a second into a thin-walled container placed adjacent to a tape-recording Geiger counter. In addition to C^{11} we find a new 20-sec. positron activity which closely follows the C^{11} in chemical tests

which are specific for CO_2. The radioactive gas was shaken with BaOH, precipitated as $BaCO_3$, filtered and followed in decay. A second and more involved test using NaOBr removed the possibility that SO_2 might have been in the precipitate. Preliminary absorption measurements give an upper limit of ~2 Mev to the 20-sec. activity. When CaF_2BF_3 enriched in B^{10} is bombarded and the gas caught by NaOH on asbestos, we find considerable enhancement of the 20-sec. period relative to the C^{11} 20.5-min. period. We, therefore, believe this short activity is C^{10} and that the 8.8-sec. activity earlier ascribed to C^{10} was due to an impurity in the boron target.

* Supported in part by Navy contract.

T8. The Beta-Ray Spectra of C^{14} and S^{35}. JANE L. BERGGREN AND ROBERT K. OSBORNE, *Massachusetts Institute of Technology*.—The beta-ray spectra of C^{14} and S^{35} were investigated with a magnetic lens spectrometer. C^{14} sources were made of elemental carbon containing 27 atom percent C^{14}, and S^{35} sources were made of "no carrier added" sulfur estimated to have a specific activity of 0.7 mc per mg of solid. Counter windows of about 0.4 mg/cm² mica were used, and sources of average thickness 0.1 mg/cm² for C^{14} and 0.05 mg/cm² for S^{35} were mounted on 0.02 mg/cm² of "Formvar." The energy distribution was found to be within 3 percent of the allowed distribution for energies above 40 kev for both spectra. The endpoints obtained were 155±2 kev for C^{14} and 169±3 kev for S^{35}. Comparison with the theory of forbidden spectra shows that both the observed energy distributions are compatible with the theoretical distribution for $\Delta I=1$ (yes) for both Fermi and Gamow-Teller interactions. For the Fermi interaction a second forbidden transition with a spin change $0\rightarrow 1$ gives a distribution for C^{14} which should be distinguishable from the observed spectrum. Careful measurements were made of the energy distribution near the end-points. It was estimated that the rest mass of the neutrino must be less than 1/100 of the electron rest mass.

T9. Some Notes on Radioactive Carbon of High Specific Activity. L. D. NORRIS AND ARTHUR H. SNELL, *Clinton National Laboratories*.—There has been described recently the preparation of several C^{14} samples, as barium carbonate, of appreciably higher specific activity than any material heretofore available.[1] The histories of these samples will be discussed, with emphasis on the radioactivity assays and the effect of sample impurities upon the calculation of carbon isotopic ratios from such assays. The samples were originally described as having specific activities corresponding to isotopic concentrations of 19 percent and 27 percent, respectively. However, more recent counting data indicates that these figures were somewhat low, and that the samples actually have specific activities corresponding to 22 percent and 32 percent, respectively. It has been pointed out that the isotopic concentrations obtained from radioactivity measurements would be minima, and that suspected impurities in the samples would make the ratios of C^{14} to total carbon appreciably higher.[1] That this is the case has been verified by F. A. Jenkins, who has observed band intensities on grating spectrograms prepared from these samples. C^{14} concentrations of 27 percent and 40 percent are obtained. Small corrections occasioned by dilution of the materials in the spectrum tubes would make these concentrations slightly higher.[2] This paper is based on work done for the Manhattan Project.

[1] L. D. Norris and Arthur H. Snell, Phys. Rev. 73, 254 (1948).
[2] F. A. Jenkins, Dep't of Physics, Univ. of Cal., Private communication.

T10. Spectrometer Measurement of Cyclotron-Induced Gamma-Radiation. DAVID E. ALBURGER, *Yale University*.*—A thin-lens magnetic spectrometer has been adapted to measure energies of gamma-rays emitted by targets under cyclotron bombardment. The cyclotron beam is deflected out through an extension tube to a target located in front of the spectrometer radiator. Gamma-rays from the target produce photo- and Compton-recoil electrons from the radiator, the energy spectrum of these being determined by varying the lens coil current. Openings in the spectrometer end-plate and a gasket arrangement permit evacuation of the spectrometer by the cyclotron pumps. To reduce the serious defocusing effect of the cyclotron stray magnetic field on the spectrometer 20 iron rings 1″ wide and ¼″ thick spaced ½″ apart along the spectrometer tube on either side of the coil effectively shield this region from the vertical disturbing field. The rings have negligible effect on the axial horizontal field of the lens coil since the spacings result in high reluctance in this direction. A preliminary electron spectrum using a lead radiator has been obtained with the gamma-rays resulting from the deuteron bombardment of PbO. From rough calibration this indicates that a gamma-ray of 0.93±0.09 Mev is present. This is in agreement with the 0.86-Mev first excited state of the O^{17} nucleus as found[1] by Pollard and Davison from the $O^{16}(dp)O^{17}$ reaction.

* Assisted by the Office of Naval Research.
[1] Ernest Pollard and Perry W. Davison, Phys. Rev. 72, 736 (1947).

T11. The Beta-Ray Spectrum of P^{32}. E. J. SCOTT, *University of Michigan*.—The shape of the continuous spectrum of the electrons emitted by P^{32} has been investigated by means of the semi-circular focussing electromagnet type of spectrometer. A Geiger tube with an extremely thin window was used to count the electrons. When a moderately thin source of low specific activity was used, the distribution followed that predicted by the theory of Fermi[1] for electron energies in excess of 200 Kev. Electrons of energies below this value showed an increasingly greater abundance than predicted by this theory. This result is nearly the same as that of Siegbahn,[2] whose corresponding value was about 100 Kev. However, when an extremely thin source of high specific activity (carrier free) was used, the distribution showed an increasing deficiency as the electron energy fell below about 1 Mev. Further experiments relative to internal scattering at the source are being continued to evaluate this discrepancy and to bring the results in accord. This research was supported in part by the Office of Naval Research.

[1] E. Fermi, Zeit. f. Physik. 88, 161 (1934).
[2] Kai Siegbahn, Phys. Rev. 70, 127 (1946).

T12. The Disintegration of Sc^{46}.* CHARLES L. PEACOCK AND ROGER G. WILKINSON, *Indiana University.*—The beta- and gamma-rays of Sc^{46} have been studied using a small 180° spectrometer of good resolution. Weak samples produced by bombarding Sc_2O_3 with the cyclotron deuteron beam, and very strong samples obtained from the Oak Ridge pile were used. Sc^{46} is found to emit a beta-ray having a maximum energy of 0.36 Mev, the resulting Ti^{46} returning to the ground state by the cascade emission of two gamma-rays with energies of 0.89 and 1.12 Mev. These results are in agreement with the work of others.[1] In addition, both neutron and deuteron induced activities are found to have a second beta-ray group of very low intensity with an end point at 1.49 Mev. This high energy group represents about 2 percent of the total number of beta-rays and is consistent with the decay scheme previously suggested.[2] Thin source technique and the results of auxiliary experiments make it unlikely that these electrons are due to scattering in the instrument, source thickness or Compton electrons. The gamma-rays are found to be converted with K-conversion coefficients of .0008 and .0004, respectively, for the 0.89 and the 1.12-Mev gamma-rays.

* Supported by the Office of Naval Research.
[1] Miller and Deutsch, Phys. Rev. **72**, 527 (A) (1947). Feister and Curtiss, J. Research Nat. Bur. Stand. **38**, 411 (1947).
[2] Peacock and Wilkinson, Phys. Rev. **72**, 251 (1947).

T13. A Search for Crossover Gamma-Ray Transitions in Co^{60} and Se^{46}. R. G. FLUHARTY AND MARTIN DEUTSCH, *Massachusetts Institute of Technology.*—The Szilard-Chalmers calcium permanganate method of measuring weak neutron intensities was used to search for photoneutrons produced from Be.* The threshold energy of the photoneutrons eliminates any effects due to the lower energy cascade gammas. Calibration by means of Na^{24} and Y^{88} demonstrated that 1 microcurie of these activities is equivalent to 15 c.p.m. of Mn^{56} by beta-ray measurements. Using 60 millicuries of Co^{60} and 15 millicuries of Sc^{46}, no effect was observed. In the case of Co^{60}, 10 c.p.m. above background could be detected, thus the abundance of gamma-rays having an energy above 1.63 Mev is less than 1.1×10^{-5} per disintegrations. By reducing background effects, 4 c.p.m. over background would be detected for Sc^{46}, and thus the high energy gamma-rays leave an abundance of less than 1.7×10^{-5} per disintegration.

* R. W. Dodson, M. Goldblatt, J. H. Sullivan, L. A. D. C., p. 260.

T14. Auger Electrons Following K-capture in Cu^{64}. C. SHARP COOK AND LAWRENCE M. LANGER, *Indiana University.**—In addition to emitting negatrons or positrons, Cu^{64} can also transform to Ni^{64} by the absorption of an electron from the K shell. The K-capture transition goes either to the ground state of Ni^{64} or infrequently to an excited state about 1.3 Mev above the ground level.[1] An intense group of Auger electrons, corresponding to the filling of the vacancy left in the K shell of Ni^{64}, has been measured in a large 180° magnetic spectrometer. The electrons were detected by a thin window counter having a transmission down to 4 kev. An accelerating potential of 4 kev, applied between the detecting slit and the counter helped drive the electrons through the counter window. The source was a chemically separated deposit of less than 0.1 mg/cm² on a backing of 0.02 mg/cm². After empirically correcting for the residual absorption of the counter window, for the self-absorption of the source, and for the efficiency of production of Auger electrons, we obtain for the ratio of K-capture to positron emission a value of 3.5 ± 1.0. This is in good agreement with the value predicted from the Fermi theory.

* This research was supported by the Frederick Gardner Cottrel. Fund of the Research Corporation and the Office of Naval Research.
[1] H. Bradt *et al.*, Hels. Phys. Acta. **19**, 219 (1946). M. Deutsch, Phys. Rev. **72**, 729 (1947).

SATURDAY MORNING AT 9:45

East Building Lecture Room
National Bureau of Standards

(F. W. LOOMIS presiding)

Invited Papers of the Division of Electron Physics

U1. Pulsed Emission Correlated with Low Temperature Direct-Current Emission Properties of Certain Oxide-Coated Cathodes. R. L. MCCORMACK AND J. CARDELL, *Raytheon*, and W. B. NOTTINGHAM, *Massachusetts Institute of Technology.*

U2. Conductivity Induced in Thin Insulating Films by Electron Bombardment. L. PENSAK, *RCA Laboratories.*

Contributed Papers on Phosphors

U3. The Temperature Dependence of the Long Period. Phosphorescence of Zinc Silicate. WALTER C. MICHELS AND LOUISE GAUS, *Bryn Mawr College.*—The integrated phosphorescent light from zinc silicate with 0.85 percent Mn* has been measured as a function of time at ten fixed temperatures between 210°K and 337°K. It is found that

the decay of phosphorescence at all temperatures can be represented as the sum of four exponential decays, each of which has a half-life independent of temperature. The observed half-lives are, in seconds, 133±7 percent, 13±10 percent, 3.5±10 percent, and 0.67±10 percent. The initial intensity corresponding to each decay rate varies with temperature in a manner similar to the intensity variation in a glow curve.[1] The constant decay rates seem to indicate that the long period phosphorescence may be due to direct decay from the trapping states, without thermal excitation to the conduction band. If so, the temperature determines only the relative populations of the various traps, and the glow curves must be interpreted making allowance for finite transition probabilities from the traps to the ground state.

* Supplied by Dr. H. C. Froelich of the General Electric Lamp Development Laboratory, Nela Park, Cleveland, Ohio.
[1] J. T. Randall, and M. H. F. Wilkins, *Proc. Roy. Soc.* **A184**, 347 (1945).

U4. Optical Properties and Constitution of Calcium Silicate-Lead Phosphors. FRANK J. STUDER AND GORTON R. FONDA, *General Electric.*—Calcium silicate phosphors were prepared by firing appropriate mixtures of calcium oxide, silica, and lead oxide. The mixtures were fired below 1200°C, in platinum boats, and an atmosphere of steam was used to facilitate completion of the reaction. The spectrum of the luminescence excited by 2537A was found to vary with the conditions of preparation of the phosphor. Three emission bands are evident at approximately 3000A, 3340A and 3500A, anyone of which may be predominant. The excitation spectrum also varies widely, having several maxima between 2000A and 3000A. When the phosphor is excited by the 2288A line from a low pressure cadmium arc, a fourth broad band appears in the emission, which peaks about 3850A and extends far enough to the longer wave lengths to be easily observed visually. X-ray analysis with a Philips Geiger-counter spectrometer demonstrates that the emission band at 3000A is due to the α-metasilicate, the one at 3500A to the β-metasilicate while the 3340A band is due to the β-ortho-silicate. During the firing process the orthosilicate is formed first by the reaction between the calcium oxide and silica in equi-molar proportions, and it reacts thereafter with additional silica to form the metasilicate.

U5. Magnetic Properties of the ZnF_2:Mn Phosphor.* PETER D. JOHNSON AND FERD E. WILLIAMS, *University of North Carolina.*—The specific magnetic susceptibility of ZnF_2:Mn and its components have been measured. The unexcited Mn^{++} is apparently in the ^6S state. The susceptibility of fluoride phosphors as a function of activator concentration coupled with energy and entropy calculations indicate that there exists appreciable spin interaction between activator ions and therefore departure from random distribution of Mn^{++} over Zn^{++} sites. Using the interaction energy obtained from susceptibility data and making the theoretically sound assumption that only non-adjacent activator ions are responsible for the emission process, the luminescent efficiency *versus* activator concentration has been successfully computed. The variation in excitation spectrum and efficiency with crystallization temperature has been qualitatively explained by the theory. The change in paramagnetic susceptibility with excitation, predicted by Williams and Eyring,[1] has been measured for ZnF_2:Mn. The phosphor was excited in a vacuum magnetic balance by radiation from a high voltage hydrogen discharge. Corrections for heating and radiation pressure were applied. The change in susceptibility corresponds to a decrease of the order of magnitude of one Bohr magneton per excited activator. The change in multiplicity has also been observed with Zn_2SiO:Mn and pure MnF_2.

* This work was supported by the Office of Naval Research.
[1] F. E. Williams and H. Eyring, J. Chem. Phys. 15, 289 (1947).

U6. Theory of Electron Retrapping in Infra-Red Phosphors.* R. C. HERMAN, C. F. MEYER, AND H. S. HOPFIELD, *The Johns Hopkins University.*—The variations of the brightness and conductivity of infra-red phosphors have been studied theoretically on the basis of a set of non-linear differential equations originally proposed by de Groot[1] and subsequently studied by others.[2] One of the important parameters in these equations is ϵ, the ratio of the cross sections for the capture of a conduction electron into an empty trap and an empty luminescent center. For intensities of the stimulating infra-red light used in most experiments the fundamental equations can be solved approximately. From the solutions of these equations it is possible to determine the value of ϵ from experimental data on the brightness and photocurrent. In this treatment the effect of light absorption in the phosphor is neglected so that the results are strictly applicable to thin samples. In the paper following by W. L. Parker and J. J. Dropkin, an example is given of the application of this theory to experimental data.

* This work was supported by the Bureau of Ordnance, U. S. Navy.
[1] W. de Groot, Physica 6, 275 (1939).
[2] R. C. Herman and C. F. Meyer, J. App. Phys. 17, 743 (1946); 18, 258 (1947); H. A. Klasens and M. E. Wise, Nature 158, 483 (1946).

U7. Stimulated Phosphorescence and Photoconductivity of Infra-Red Phosphors.* W. L. PARKER AND J. J. DROPKIN, *Polytechnic Institute of Brooklyn.*—The photoconductivity and brightness of an infra-red phosphor under stimulation have been measured simultaneously. The phosphor polarizes rapidly with resultant decrease in the current. A technique for depolarizing the sample has been worked out and will be described. This permits the measurement of the decay curves of both brightness and photoconductivity as a function of the time of stimulation. Logarithmic plots of brightness *vs.* time, photocurrent *vs.* time, and photocurrent *vs.* brightness become straight lines at moderately small times. If the brightness and photocurrent are extrapolated to zero time to get the initial values B_0 and i_0, then a plot of i/i_0 *vs.* $(Bi_0)/(B_0i)$ should be a normalized plot of the number of conduction electrons *vs.* the number of empty luminescent centers. The experimental data show approximate agreement with the theoretical curves of this type described by Herman, Meyer, and Hopfield in the preceding paper. The data indicate that the ratio of the cross sections for retrapping

and luminescence is less than one—probably of the order of one-tenth for the samples studies.

* This work was supported by the Bureau of Ships, U. S. Navy.

U8. The Response of Certain Inorganic Phosphors in the Extreme Ultraviolet Region.* E. M. PELL AND D. H. TOMBOULIAN, *Cornell University.*—In the investigation of the use of photomultipliers for the detection of ultra-soft x-rays, a preliminary study of certain fluorescent substances was undertaken with the object of finding their responses to radiation in the 100 to 400A region. A grazing incidence vacuum spectrograph was used to disperse the radiation. A highly condensed capillary spark discharge, as well as the L-emission band from an aluminum target, was utilized as a source. A thin layer of the phosphor to be tested was deposited on a strip of celluloid which was placed in contact with the Rowland circle and backed with orthochromatic film. The tests indicate that tetragonal $CaWO_4$:Pb, $BaSO_4$:$PbSO_4$, and tetragonal $CaWO_4$:[W] give excellent conversion in this region. Monoclinic Mg_2WO_5:[W] gives fair conversion, while rhombohedral Zn_2SiO_4:Mn, monoclinic $CdWO_4$:[W], and $Ca_3(PO_4)_2$:Ce respond weakly. No definite evidence of a significant variation of conversion efficiency with incident intensity has been found over an intensity range of the order of 1000:1. We believe the response of phosphors in this region has not been investigated previously. Acknowledgments are due Mr. H. W. Leverenz of RCA Laboratories for the samples used in the investigation.

* Assisted by the Office of Naval Research.

SATURDAY MORNING AT 9:45

Department of Commerce Auditorium

(J. C. SLATER presiding)

Conclusion of the Symposium on Radiofrequency Spectroscopy

V1. Microwave Resonance Absorption in Paramagnetic Salts. P. R. WEISS, *Rutgers University.* (30 min.)

V2. Microwave Resonance Absorption in Ferromagnetic Materials. CHARLES KITTEL, *Bell Telephone Laboratories.* (30 min.)

V3. Precision Measurement of Molecular Rotation Frequencies. D. K. COLES, *Westinghouse Electric Corporation.* (20 min.)

V4. Rotational Spectra of Linear Molecules. M. W. P. STRANDBERG, *Massachusetts Institute of Technology.* (15 min.)

V5. Nuclear Properties Determined from Microwave Spectroscopy. C. H. TOWNES, *Columbia University.* (25 min.)

V6. Use of Microwave Spectroscopy for Studies of Molecular Structure. E. BRIGHT WILSON, *Harvard University.* (30 min.)

SATURDAY AFTERNOON AT 2:15

Department of Commerce Auditorium

(LEON BRILLOUIN presiding)

Invited Papers on Computing Machines

W1. Computing Machines. HOWARD AIKEN, *Harvard University.* (60 min.)

W2. Status of Large Scale Computing Devices in the United States. R. L. SNYDER, *University of Pennsylvania.* (30 min.)

W3. The IBM Selective Sequence Electronic Calculator. W. J. ECKERT, *International Business Machines.* (30 min.)

SATURDAY AFTERNOON AT 2:00

Lisner Auditorium

(M. A. TUVE presiding)

Apparatus of Nuclear Physics

X1. Redesign of the Princeton Cyclotron to Yield 18 Mev Protons.* M. G. WHITE, H. W. FULBRIGHT, P. GUGELOT, R. R. BUSH, *Princeton University.*—The 35" Princeton cyclotron magnet can be operated at 19,500 gauss with a maximum $H\rho$ at $n=0.2$ of 6.5×10^5. Full utilization of this $H\rho$ would give 21 Mev protons, but if operated as a conventional cyclotron would require about 500 kev energy gain perrevolution and the necessary radio frequency power at 29.3 megacycles would be very high. A redesign to frequency-modulation operation has thus far yielded an inside average current of 1–1.5 microamperes at 18 Mev, with only 10 kev on the single dee. The central field was 18,300 gauss. A rotating vacuum condenser varies the frequency by 8 percent at repetition rates up to 3600 c.p.s. The over-all stability and reliability of operation have been gratifying. The beam current varies with modulator repetition frequency in close agreement with the theory of Bohm and Foldy, but the variation of beam current with dee voltage is complicated by interactions between dee voltage and ion-source. Beam homogeneity in energy is surprisingly good, about 100 kv, showing that the center of rotation is more sharply defined than is customary with cyclotrons. Measurements on an internal probe show very little activity at distances greater than 5×10^{-2} cm from the inside edge.

* Supported in part by Navy contract.

X2. Gas Scattering in the Electron Synchrotron. J. MAYO GREENBERG AND T. H. BERLIN, *Johns Hopkins University.*—Elastic single scattering losses from an equilibrium orbit in a circular synchrotron have been obtained as a function of the residual gas pressure and the electron injection energy. The losses have been calculated for a synchrotron of radius 100 cm having a doughnut of radius 4 cm and a 20 c.p.s. magnetic field with peak value 8000 gauss. Injection energies range from 40 to 500 kev and pressures from 10^{-3} to 10^{-6} mm Hg. At 10^{-5} mm the losses range from 1.1 to 4.8 percent; at 10^{-4} mm from 7.1 to 23.4 percent; and at 10^{-3} mm from 14 to 36 percent. The actual losses are greater because of the scattering from the oscillating orbits,[1] the inelastic scattering, and the multiple scattering. For pressures less than 10^{-4} mm, the multiple scattering contributes very considerably to the loss. Calculations are in progress which will yield the scattering losses from the oscillating orbits, the contribution of inelastic scattering, and a more accurate estimation of the contribution of multiple scattering.

[1] D. M. Dennison and T. H. Berlin, Phys. Rev. **70**, 58 (1946).

X3. Two Cavity Operations of Yale Linear Electron Accelerator. R. L. MCCARTHY, J. A. LOCKWOOD, P. J. RICE, H. L. SCHULTZ, *Yale University.**—Description of this accelerator[1] and results of preliminary operation of single cavities with respect to electron energy spectra and beam characteristics have been reported previously.[2] A highly stable frequency source has been employed to drive two triode amplifiers. Each amplifier feeds one resonator of a set of two mutually uncoupled resonators of 3 in. and 7 in. length whose resonant frequencies have been adjusted to be the same. Relative phase between the oscillations in each were controlled by a phase shifting section between one amplifier and its associated resonator. Results of experiments on acceleration of electrons in this system will be reported in detail.

* Assisted by the Office of Naval Research.
[1] H. L. Schultz *et al.*, Phys. Rev. **72**, 346 (1947).
[2] Bull. Am. Phys. Soc. 1947 Annual Meeting.

X4. Electron Ballistics in the Yale Linear Accelerator. C. L. CLARK, *Yale University.**—Results will be presented of detailed calculations on the motion of electrons in the first two cavities of the Yale linear accelerator.[1] In this design cavities driven by separate amplifiers operating from a common master oscillator are kept so loosely coupled that *the relative phase of the fields in successive stages can be held at any desired value.* General features of both axial and radial motions will be discussed, and their bearing on design problems indicated. Numerical results to be reported concern homogeneity,[1] bunching, and focusing. The compatibility of these last will be discussed, and the argument from Earnshaw's theorem[2] will be considered in the light of the arbitrariness of phases in the Yale design. Assumed parameters are approximately as follows: continuous injection at 5 kev; first cavity 3 in. long, second cavity 7 in., each dissipating 200 Kw in the TM_{010} mode at 600 Mc/sec. The chief departure from experimental conditions[3] lies in assuming rectangular pulses, those obtained in practice being more nearly triangular.

* Assisted by the Office of Naval Research.
[1] H. L. Schultz *et al.*, Phys. Rev. **72**, 346 (1947).
[2] Ginzton, Hansen, and Kennedy, Rev. Sci. Inst. **19**, 89 (1948) and references therein cited.
[3] H. L. Schultz *et al.*, Bull. Am. Phys. Soc. **23**, 29 (1948).

X5. Compact Electrostatic Generator for Positive Ion Acceleration.* C. P. SWANN AND E. L. HUDSPETH, *Bartol Research Foundation.*—The Bartol generator[1] has been greatly improved in reliability of operation through changes made during the past several months. Textolite control rods, which caused one fire, have been replaced by Pyrex rods. Storage tanks were installed so that a freon-nitrogen mixture may be used as the insulating gas. An all-glass ion source, of the capillary type, operating with 120 volts d.c. and a 15-watt oxide-coated filament, gives an arc of over 500 milliamperes. Tube currents vary from a few tenths to several microamperes of resolved

ions. The freon-nitrogen mixture may be pumped from the pressure vessel, the latter hoisted to expose the main elements of the generator, the pressure vessel replaced and operation resumed in less than three hours. Maximum operating voltage at present is 1.75 Mev, which corresponds to 350 kilovolts per foot of accelerating tube. This limit is imposed by the tube itself, and indications are that it may be increased quite appreciably.

* Assisted by the Office of Naval Research.
[1] W. E. Danforth and E. L. Hudspeth, Phys. Rev. 60, 170 (1941). An account of all phases of work on this generator will be published soon by Danforth, Hudspeth, Mandeville, and Swann.

X6. Methane Proportional Counter for Beta-Counting. C. J. BORKOWSKI AND E. FAIRSTEIN, *Oak Ridge National Laboratory.*—Counters filled with methane and operated in the proportional region with a gas amplification of 10,000 have been developed for precision counting of beta particles, gamma rays, X-rays, and soft conversion electrons. Plateaux of 400 volts are obtained with a slope of 1 percent or less per 100 volts. Using 0.5 mil tungsten center wire and methane at one atmosphere, the operating voltage is 2200 volts. With a specially designed chamber similar to the one described by J. A. Simpson[1] and a continuous flow of methane at atmospheric pressure, the counting of soft radiation is made possible without window or air absorption. H^3 beta-particles have been counted from solid sources in this type of counter. Counting yields as high as 75 percent are obtained for beta-emitters like C^{14}, S^{35}, P^{32}. These counters have been operated continuously for more than a year with no change of characteristics.

High speed counting is possible since the coincidence loss is only 1 percent per 100,000 counts per minute.

Energies of beta particles below 50 kev may be determined with this type counter since the counter is operating in the proportional region. This document is based on work performed for the Atomic Energy Project.

[1] J. A. Simpson, Jr., Rev. Sci. Inst. 18, 884 (1947).

X7. Deadtime Theory.* S. S. FRIEDLAND, *Memorial Hospital and New York University,* AND A. D. KRUMBEIN, *New York University.*—The deadtime of a self quenching counter is defined as the time it takes the positive ion sheath formed in the vicinity of the central wire, to move from there to a distance such that the field surrounding the wire will have recovered sufficiently to support an observable avalanche. Stever[1] has derived an expression for the deadtime. In his derivation, he assumed the mobility of the positive ion sheath was constant even though it was moving through a region of variable E/p. An examination of Hershey's[2] data, shows that we can approximate the variation of the mobility in deadtime region by the expression $k = Ar$, where k is the mobility, r is the distance of the sheath from the wire center, and A is a constant. Stever's experimental values disagree with theory by a factor of 4. If we insert the above expression into his equations, and again solve for the dead-time, we find that the experimental values now agree with theory within 2 percent.

* This work was supported in part by the Office of Naval Research.
[1] H. G. Stever, Phys. Rev. 61, 38 (1942).
[2] A. V. Hershey, Phys. Rev. 56, 908 (1939).

X8. A Proposed Self-Controlled Cloud Chamber. MARTIN J. COHEN, *Princeton University.**—Preliminary results indicate that the functions of a Wilson cloud chamber and a pulse ionization chamber can be performed in the same volume of gas. The mechanism is the following: A heavy ionizing event produces electrons and positive ions in the gas mixture (argon and alcohol). The electrons are collected as such within 10 microseconds by the signal electrode which is connected to a high gain, wide band amplifier (model 100). After amplification the signal short-circuits the electron collection field and expands the cloud chamber to produce "tracks" on the less mobile positive ions. A conventional cloud chamber with a rubber diaphragm is used. The signal electrode is a transparent conducting layer on the front surface of the chamber. It is connected directly to the first grid of the preamplifier. The negative potential is applied to an insulated, perforated brass plate to which the black velvet background is also attached. Measurements show that the condensible vapor in the cloud chamber does not capture electrons to a sufficient extent to preclude operation of the combination of a cloud and ion chamber. Ethyl, N-propyl, iso-amyl alcohols and cyclohexanol have been tried.

* This work is performed under Contract with the Office of Naval Research.

X9. Background Eradication of Nuclear Emulsions by Accelerated Fading of the Latent Image. HERMAN YAGODA AND NATHAN KAPLAN, *National Institute of Health.*—A study of the factors controlling the rate of fading of the latent image produced by densely ionizing radiations in fine-grained emulsions reveal that traces of H_2O_2 in the vapor phase cause very rapid destruction of the latent image. After desiccation of the plate the emulsion is restored to its original sensitivity. This permits the eradication of the accumulated background of alpha-ray tracks arising from continuous registration by internal radioactive impurities prior to exposure to feeble sources of radiation under study. By maintaining the exposure in a dry, H_2O_2 free atmosphere at low temperature quantitative recording is possible for periods longer than 2 months. Under these conditions single α-tracks accumulate at a rate of 8–100/cm²/day depending on emulsion purity and thickness. Low energy alpha-ray stars originating from successive decay of traces of Th and Rd Th in the gelatin generate ~0.3 multiple events/cm²/day. Near sea level, the controlled exposure indicates a daily rate of proton and meson tracks of 0.03–.06/cm^{-2}; and a population of 0.0005/cm² nuclear evaporations induced by cosmic radiations. This method is applicable only to fine-grained nuclear type emulsions as Eastman NTA and Ilford Conc. With coarse-grained, light-sensitive emulsions the H_2O_2 vapor produces pseudophotographic effects. Mechanism of spontaneous facing will be described.

X10. Particle Tracks in Emulsions Showing Grain Gradation. W. VAN DER GRINTEN, *General Electric Company.*—Current photographic processing techniques, carrying the development of nuclear plates practically to completion do not lead to significant differentiation among the

amounts of silver precipitated on individual grains. A new technique for producing such differentiation will be described involving the use of a special developer combined with partial development. Thus silver halid grains, struck by a particle of low specific ionization, produce a track composed of small transparent silver specks, whereas similar grains, struck by a particle of high specific ionization produce larger and opaque specks. This "grain gradation" greatly facilitates the differentiation between alpha and proton tracks. So far, low-concentration developing agents active only in the form of ions carrying two or more negative charges have been found to produce grain gradation. The bromide concentration is not critical and may be kept low. This allows one to bring practically all developable grains to the level of visibility. A minimum developer temperature exists below which grain gradation disappears. It is believed that the rate of growth of individual development centers has been homogenized under present conditions and that, consequently, grain gradation is a measure of the number of development centers per grain. Photomicrographs, including betatron stars, will be shown.

X11. Removal of Latent Image in the Powell Photographic Plate Technique. JOSEPH DE FELICE, *Stevens Institute of Technology.* (*Introduced by G. J. Yevick*).—For the absolute count of cosmic ray events at high altitudes it would be convenient to have plates free from tracks prior to the balloon flight. The procedure of Liebermann and Barschall[1] proved satisfactory for the removal of all latent images from 100 micron Ilford C2 plates. The effect of this process on the grain count for alpha tracks from uranium was determined as follows: Two groups of plates were used; the first group was put through the removal process while the second group was untouched. These two groups were then loaded with uranyl nitrate. The grain density (number of grains per unit length) of the first group turned out to be about one-fifth less than that of the second group. This is compensated in part by the fact that the length of the tracks in the first group was slightly longer (about one-tenth) than the second group. This appears to be due to a swelling of the emulsion. The absolute number of grains per track in the first group was about one-tenth less than the second.

[1] Liebermann and Barschall, Rev. Sci. Inst. 14, 89, 1943.

X12. Scintillation Counting with Anthracene. P. R. BELL AND R. C. DAVIS, *Oak Ridge National Laboratory.**—Anthracene has proved more satisfactory for use with 1P21 photomultiplier as a scintillation counter than napthalene. Cobalt 60 gamma-rays produce 3.5 times larger pulses in anthracene than in naphthalene permitting the use of a lower background counting rate. A polonium beryllium neutron source gave five times greater counting rate with anthracene than with naphthalene. The maximum pulse size was also five times as great in anthracene. The counts were shown to be due to fast neutrons by an absorption curve in lead and in cadmium. The fast neutron detection efficiency seems to be 10–15 percent.

* This work as done under Contract No. W-35-058, eng. 71.

X13. A Gamma-Ray Isodosimeter. L. D. MARINELLI AND G. J. HINE, *Sloan-Kettering Institute.*—The investigation of the spatial variation of γ-ray dose in the vicinity of extended 3-dimensional sources is tedious and cumbersome. This applies to both experimental methods and numerical calculations. The apparatus to be described records automatically lines of equal radiation doses (isodoses) in a given plane. The isodose curves obtained in different parallel planes complete the radiation field of an extended γ-ray source. The instrument consists of an ionization chamber, a feed-back amplifier and a servomechanism. The latter moves the chamber linearly to or from the slowly rotating γ-ray source according to whether the amplified ionization current is smaller or greater than a pre-set value. The motion of the chamber is recorded on a platform which rotates synchronously with the source. Preliminary results show good agreement with calculations made of linear sources.[1] Further observations with metal foils irradiated in nuclear reactors will be presented.

[1] E. H. Quimby, Radiology 43, 572, 1944.

SATURDAY AFTERNOON AT 2:00

Hall of Government, Room 102

(D. K. COLES presiding)

Molecular Structure and Nuclear Moments

Y1. Nuclear Quadrupole Moments of N^{14} and I^{127}.* C. H. TOWNES, *Columbia University.*—Nuclear quadrupole moments of Cl and Br have been obtained from microwave measurements of quadrupole couplings and using atomic orbitals as an approximation to molecular wave functions near the nucleus.[1] Atomic beam measurement of the Cl^{35} quadrupole moment shows that the result obtained is essentially correct in the case of Cl^{37}. A similar calculation from microwave data gives a value for the I^{127} quadrupole moment -0.75×10^{-24} cm^2, somewhat larger than the value $-0.45\pm.15\times10^{-24}$ obtained from atomic emission spectra.[2] The N^{14} quadrupole is more difficult to obtain because the atomic orbital approximation is less accurate for light elements and because of uncertainties in the nitrogen bond structure. However, a comparison of the N^{14} quadrupole coupling in various molecules shows that

the normal nitrogen bonds involve considerable s,p hybridization. This conclusion, as well as comparison with the quadrupole coupling in AsF_3, allows a fairly definite determination of the quadrupole moment sign as positive and an approximate evaluation of its magnitude as 0.02 $\times 10^{-24}$ cm^2.

* Work supported by the Signal Corps.
[1] C. H. Townes, Phys. Rev. **71**, 909 (1947).
[2] L. Davis, B. T. Feld, C. W. Zabel, and J. R. Zacharias, Phys. Rev. **73**, 525 (1948).
[3] K. Murakawa, Zeits. f. Physik. **114**, 651 (1939).

Y2. Microwave Rotational Absorption in D_2O.* M. W. P. STRANDBERG, *Massachusetts Institute of Technology.*—A rotational absorption in heavy water, at 20460.40 mc/sec. has been observed and has been identified on the basis of its Stark effect. The observed Stark pattern shows a simple displacement of the absorption according to the formula,

$$\Delta\nu = 1.052E^2 \text{ mc/sec.}$$

where E is the electric field strength in kilovolts per centimeter. The line intensity is the order of magnitude of that of the $6_{-3}-5_{-1}$ transition in H_2O and the 5_1-5_0 transition in HDO. On the basis of the known term values[1] no obvious identification is possible. However, if the relative values of the 3_{-2} and 2_2 terms are interchanged a reasonable fit can be made with the observed Stark effect. If the term value of the 3_{-2} level is taken to be 73.81 cm^{-1} and the 2_2 level taken as 74.50 cm^{-1} the theoretical Stark effect for this transition proves to be

$$\Delta\nu = \mu^2E^2(.2472-.01261M^2) \text{ mc/sec.}$$

This is fitted to the observed pattern with a dipole moment of 2.04±.04 Debye units. Though some dependence on the magnetic quantum number is indicated the fit seems good enough since the dipole moment is reasonable and the predicted intensity[2] checks well with the observed value. On the basis of this identification a relation between the extreme reciprocal moments of inertia is readily calculated as

$$a = .2502 + 3.1994c \text{ cm}^{-1}.$$

Minimizing the change in the Fuson, Randall, Dennison values $a = 15.38$, $c = 4.83$, this equation gives $a = 15.55$ cm^{-1} and $c = 4.79$ cm^{-1}.

* This work has been supported in part by the Signal Corps, the Air Materiel Command, and O.N.R.
[1] N. Fuson, H. M. Randall, and D. M. Dennison, Phys. Rev. **56**, 982 (1939).
[2] G. W. King, R. M. Hainer, and P. C. Cross, Phys. Rev. **71**, 433 (1947).

Y3. Pure Rotational Spectrum of AsF_3. B. P. DAILEY, K. RUSINOW, R. G. SHULMAN, AND C. H. TOWNES,* *Columbia University.*—Twelve lines of the rotational transition $J=1\rightarrow J=2$ of AsF_3 were observed by the Stark modulation method near 23,500 mc. Ten of these lines are produced by the $K=0$ and $K=1$ levels of the ground vibrational state. They fit the hyperfine pattern expected from the nuclear quadrupole moment of As. This confirms a spin of $\frac{3}{2}$ for As^{75}. The remaining two lines are probably due to excited vibrational states. Calculated intensities are approximately 10^{-7} nepers/cm. From the frequencies of the observed lines, values of $B_0 = .19610$ cm^{-1} and of $I_B = 142.7\ 10^{-40}$ g-cm^2 may be calculated. Assuming the F−As−F angle 100±5°, the As−F internuclear distance is 1.712±.006A as compared with 1.73±.02A from electron diffraction measurements.[1] The quadrupole coupling constant, $eQ(\partial^2V/\partial z^2)$, is −235 mc. Since the quadrupole moment as As^{75} is 0.3×10^{-24} cm^2, this large coupling indicates considerable s,p hybridization of the As bond rather than a pure p-orbital.

* Work supported by the Signal Corps.
[1] L. Pauling and L. O. Brockway, J. Am. Chem. Soc. **57**, 2685 (1935).

Y4. Microwave Zeeman Spectra of Methyl-Chloride and Some Nuclear Properties of Chlorine.* C. K. JEN, *Harvard University.*—It has been shown previously[1] that the microwave Zeeman spectrum of $N^{14}H_3$ can be satisfactorily explained on the basis of approximately equal g-factors for nuclear and molecular magnetic moments in the spin-rotation coupling scheme. This explanation was later substantiated by experiments on $N^{15}H_3$ which, having no nuclear electric quadrupole coupling, yielded directly a molecular g-factor for $N^{15}H_3$ in good agreement with the molecular g-factor deduced theoretically for $N^{14}H_3$. Further experiments have since been done on CH_3Cl. The $J=0\rightarrow1$ rotational lines for both CH_3Cl^{35} and CH_3Cl^{37}, already published,[2] have been found here, using a resonant cavity as the absorption cell. In a weak magnetic field, the central line for either molecule remains at the same position but is considerably weakened, while each of the two side lines is split into a symmetrically displaced doublet. Within the experimental limitations of resolution and sensitivity, the Zeeman pattern and the frequency separations are consistent with theoretical calculations, if we assume, for either Cl isotope, a spin $I=\frac{3}{2}$ together with the known value for the nuclear g-factor, and a negligible contribution due to the molecular magnetic moment.

* This research is supported jointly by the Office of Naval Research and the Signal Corps.
[1] C. K. Jen, Bulletin, Am. Phys. Soc., Vol. 23, No. 2, January, 1948 (abstract G2).
[2] W. Gordy, J. W. Simons, and A. G. Smith, Phys. Rev. **72**, 344 (1947).

Y5. Microwave Determination of the Molecular Structures and Nuclear Couplings of Methyl Chloride, Methyl Bromide, and Methyl Iodide.* JAMES W. SIMMONS, WALTER GORDY, AND A. G. SMITH, *Duke University.*—Accurate measurements on the pure rotation spectra of methyl chloride, bromide, and iodide have been made with multiples of the standard 10 mc frequency of WWV. The measurements, with the I_A values** previously determined by infra-red spectroscopy, allow a complete determination of the structures of CH_3Cl and CH_3Br. The I_B values for the ground vibrational state in g-cm$^2\times10^{-40}$ are: 63.1141 for CH_3Cl^{35}, 64.1011 for CH_3Cl^{37}, 87.6836 for CH_3Br^{79}, 88.0184 for CH_3Br^{81}, and 111.506 for CH_3I^{127}. The molecular dimensions obtained are: for methyl chloride, $d_{CH}=1.107$A, $d_{CCl}=1.779_2$A, $\angle HCH=109°\ 52'$; for methyl bromide, $d_{CH}=1.100$A, $d_{CBr}=1.940_8$A, $\angle HCH=111°\ 10'$; for methyl iodide, $d_{CH}=1.100$A, $d_{Cl}=2.136$A, $\angle HCH=111°\ 10'$ (assumed). The nuclear quadrupole couplings, $eQ(\partial^2V/\partial z^2)$, are: for Cl^{35}, −75.13 mc; for Cl^{37},

-59.03 mc; for Br^{79}, 577.0 mc, for Br^{81} 482.0, for I^{127}, -1931.5 mc. Second-order effects in the hyperfine structure were observed for methyl bromide and methyl iodide.

* The research described in this report was supported by Contract with the Army Air Forces.
** The value of h used is 6.624×10^{-27} erg sec.

Y6. A Note on the Stark Effect in Diatomic Molecules. W. A. NIERENBERG AND M. SLOTNICK, *Columbia University.*—The hyperfine structure arising from the orientation dependent interaction of each nucleus with the other charges of a polar diatomic molecule in a constant electric field are considered. For weak fields, a method is given for determining the level splittings for a general type of nuclear interaction, but where one nucleus interacts more strongly than the other. For both weak and strong fields, explicit formulas are given for the case of a quadrupole interaction of one of the nuclei (nucleus 1) and a cosine or "$I\cdot J$" interaction of both nuclei. The "$I_2\cdot J$" interaction removes the degeneracy with respect to nucleus 2 and causes an additional splitting of the usual quadrupole hyperfine structure levels.[1] This splitting is observed in recent molecular beam experiments of Trischka with CsF and KF. It is found that the perturbation due to $I\cdot J$ interactions may be treated as independent of the mixing of J states arising from a strong electric field.

[1] U. Fano, J. Research Nat. Bur. Stand. March, 1948.

Y7. Saturation Effects in Microwave Spectra.* WILLIAM J. PIETENPOL, JOHN D. ROGERS, AND DUDLEY WILLIAMS, *The Ohio State University.*—Saturation effects in microwave spectra have been observed by numerous investigators. The published data on the changes in absorption coefficients are in essential agreement, but data on line broadening are in disagreement. Townes[1] and Pond and Cannon[2] report pronounced line broadening, while Gordy and Kessler[3] and Smith and Carter[4] have reported their failure to observe appreciable broadening. The results reported here are in essential agreement with those of Pond and Cannon. Changes in observed line heights and widths of the ammonia 6,6 line with changes in incident power level will be discussed. The observed results can be interpreted in terms of a disturbance of the normal Boltzmann distribution of molecules between ground and excited state when radiation density is high.

* Work done under Contract W28-099-ac-179 between Watson Laboratories of the Air Materiel Command and the Ohio State University Research Foundation.
[1] C. H. Townes, Phys. Rev. **70**, 665 (1946).
[2] T. A. Pond and W. F. Cannon, Phys. Rev. **72**, 1121 (1947).
[3] W. Gordy and M. Kessler, Phys. Rev. **71**, 640 (1947).
[4] W. V. Smith and R. L. Carter, Phys. Rev. **72**, 638 (1947).

Y8. New Bands in the Vibration-Rotation Spectrum of Water Vapor. W. S. BENEDICT, *National Bureau of Standards.*—Reinvestigation of the vibration-rotation spectrum of H_2O from the atmospheric absorption in the solar spectrum $\angle6600$ to $\angle13495$[1] has yielded several new features. Over 1600 lines have been assigned on the basis of relative intensity and constant combination differences in the ground state, to higher rotational transitions in known bands, and to ten new, relatively weak, satellite bands. Some of the new bands are of the parallel type. Perturbations of rotational levels of one vibrational state by its neighbors make it difficult to obtain accurate effective moments of inertia. The identification, position of the zero level, approximate effective reciprocals of inertia, and approximate relative intensity of the new bands are listed:

Upper Level Symmetry								
V_1	V_2	V_3	Species	ν_0 (cm^{-1})	Ae (cm^{-1})	Be (cm^{-1})	Ce (cm^{-1})	Intensity [(111) = 50]
1	3	0	A_1	8273.98	39.9	14.7	8.7	3
0	3	1	B_1	8373.90	38.9	14.7	8.8	15
{2	1	0}	A_1	8761.5	28.1	14.5	8.9	4
{0	1	2}	A_1	9000.14	28.9	14.4	8.9	6
0	4	1	B_1	9834.9	45.8	14.9	8.6	1
1	2	1	B_1	10328.9	32.1	14.5	8.6	12
1	0	2	A_1	10867.8	25.3	14.1	8.9	5
1	3	1	B_1	11813.44	37.1	14.6	8.4	1
1	1	2	A_1	12407.65	27.8	14.2	8.7	1
2	2	1	B_1	13562.65	31.4	14.2	8.5	1

[1] H. D. Babcock and C. E. Moore, Carnegie Inst., Washington, Publication 579 (1947).

Y9. An Analysis of the 2.6 Mu Band of H_2S by Punched-Card Methods.* GILBERT W. KING AND R. M. HAINER, *Arthur D. Little, Inc.*—A rather poorly resolved band of H_2S at 2.6 mu was described[1] several years ago, but has hitherto not been analyzed. Using punched-card methods we assumed moments of inertia for the ground state obtained from an analysis[2] of the band at 9911 cm^{-1} and calculated the expected spectrum for thirty-five choices of upper-state moments and ten different slit-shape functions. A fairly satisfactory fit was found for moments 2.71, 2.90, 6.02×10^{-40} g-cm^2 and band center 3789 cm^{-1}. The induced dipole is definitely parallel to the least moment, although excellent fits in the P and R branch could equally well be made for the moment parallel to the intermediate moment. The effective slit width for the observed spectrum was determined, and seems to change from 1 cm^{-1} in the P branch to 5 cm^{-1} in the R branch. The appearance of the calculated and observed spectrum was computed for wider slits (10 cm^{-1}) and found to agree very well with prism data.[3]

* This work was done with support of the Office of Naval Research.
[1] H. H. Nielsen and E. F. Barker, Phys. Rev. **37**, 727 (1931).
[2] P. C. Cross and B. L. Crawford, Jr., J. Chem. Phys. **5**, 621 (1937).
[3] E. A. Wilson, Ph.D. Thesis, Brown University, 1947.

Y10. Infra-Red Absorption Spectra of Ethyl and of *n*-Propyl Alcohol. E. K. PLYLER AND S. L. KRUEGEL, *National Bureau of Standards.*—The infra-red absorption spectra of the vapors of ethyl and of *n*-propyl alcohol have been measured in the region from 2 to 40 microns. To obtain good resolution throughout this region, prisms of LiF, NaCl, KBr, and TlBr−I were used. In ethyl alcohol, 19 bands have been observed, 7 of which are sufficiently strong to be found with cells of short length. A meter path was required to bring out some of the weaker bands. Some of the bands have been related to the C−H, O−H, and C−O vibrations within the molecule. Considering the arrangement of the two C and the O atoms as a linear triatomic molecule, 3 observed bands can be related to the vibrations of this skeletal structure. A band found in the region of 40μ is attributed to the hindered rotation within the molecule. Seventeen bands have been observed in the

vapor of *n*-propyl alcohol. The classification of these bands in relation to the structure of the molecule is similar to that for ethyl alcohol, except in the skeletal vibrations where three C and an O are involved. This gives rise to additional bands in the 6.5 to 13μ region.

Y11. Force Constant Calculations for the X_4Y_6 Molecule. HAROLD W. WOOLLEY, *National Bureau of Standards.*—Force constant calculations have been carried out for the tetrahedrally symmetric X_4Y_6 molecule using symmetry coordinates and the matrix methods of Wilson. With 24 internal degrees of freedom, there are 300 quadratic potential energy terms involving 19 force constants. Vibrational frequencies of the A_1, E, and T_1 symmetry classes involve quadratic equations while the T_2 symmetry class has a quartic equation. Only the T_1 vibrations are inactive in both infra-red and Raman, With only 8 frequencies observable in principle and without data for the isotopic molecules, the force constants are not definitely determinable. Examples of the X_4Y_6 molecule are P_4O_6 and As_4O_6. Calculations have been made in regard to a postulated B_4O_6 molecule, using force constants and observed frequencies based on other molecules involving B and O, including solid $(B_2O_3)_x$.

Y12. An Explicit Solution of the Problem of the Asymmetric Rotator According to Quantum Mechanics.* ENOS E. WITMER, *University of Pennsylvania.*—An explicit and exact solution of the problem of the asymmetric rotator according to quantum mechanics has been obtained. Both the energy and the wave functions are in the form of infinite series. This solution is an elaboration or improvement of the one previously published by the writer.[1] The new solution takes account of *K*-type doubling and gives all the wave functions. This solution is in very close correspondence with the solution of the asymmetric rotator according to the old quantum theory published by the writer.[2] As in that theory the domain of variation of the parameters is divided into two parts and different expansions are used in the two parts. The correspondence principle and numerical checks lead us to believe that the new series for each of the partial domains are convergent over the whole of that partial domain. The formulas may be written so that the coefficients after the first one are functions of the quantum numbers alone. Numerical tables of the coefficients in these series are being made.

* Supported by Bureau of Ships, Department of the Navy.
[1] E. E. Witmer, Proc. Nat. Acad. Sci. **13**, 60 (1927).
[2] E. E. Witmer, Proc. Nat. Acad. Sci. **12**, 602 (1926).

Y13. Fluorescence of Fluorobenzene.* ARNOLD M. BASS AND H. SPONER, *Duke University.*—The fluorescence of fluorobenzene vapor corresponding to the absorption spectrum in the near ultraviolet was examined. The fluorescence was excited by light from various sparks, chiefly a Sn spark which has a strong line at 2643A practically coincident with the 0, 0 absorption band. The observed fluorescence conforms to the conditions of "high pressure" fluorescence. In order to control the exciting wave-length region, cut-off filters of organic solutions were used. The spectrum was photographed in a medium Bausch and Lomb quartz spectrograph. It extends from about 2640 to 2900A and consists of discrete bands the number of which varies with conditions of excitation. Discrete fluorescence bands of fluorobenzene have been observed before by Monypenny and Russell[1] upon exciting the vapor by the light from a mercury arc. A comparison between their results and ours gives only partial agreement. A preliminary analysis reveals that ground state frequencies of 800,999 and 1027 cm^{-1} occur single, and in multiples and combinations. These frequencies have also been found in the absorption spectrum and in the Raman effect. Although most bands can be explained in analogy to the absorption spectrum, there are several interesting differences between fluorescence and absorption bands which need further clarification.

* This work was supported by the Office of Naval Research.
[1] H. W. Monypenny and A. Russell, J. Chem. Soc. 2436 (1929).

SATURDAY AFTERNOON AT 2:00

Hall of Government, Room 1

(D. J. HUGHES presiding)

Artificial Radioactive Substances

Z1. Radioactive Ga^{67}, Ge^{69}, As^{73}, and As^{74}. D. A. MCCOWN, L. L. WOODWARD, M. L. POOL, AND H. L. FINSTON, *The Ohio State University.*—Ge^{70}, in the form of GeO_2 powder, enriched electromagnetically from 21.2 percent to about 90 percent,* has been bombarded with alpha-particles with simultaneous bombardment of GeO_2 containing germanium of normal isotopic constituency. Both samples showed a strong activity of 7.1-hour half-life which has been assigned to Se^{73}. Neither sample showed evidence of the 50-hour As^{73} period. The existence of a 50-hour arsenic period is thus very improbable. Gallium has been bombarded with deuterons to obtain confirmation of the 195-day Ge^{69} period. From intensity considerations this period should have occurred if it exists. No evidence of this period was found. The above alpha-particle bombardment of enriched Ge^{70} also locates the 90-day arsenic period as an As^{73} isotope. The half-life of As^{74}, as a result of alpha-particle bombardment of gallium followed over a

period of 10 half-lives, and also from deuteron bombardment of germanium followed over a period of 8 half-lives, is found to be 17.5±0.1 days. The half-life of Ga^{67}, from alpha-particle bombardment of zinc followed over a period of 10 half-lives is found to be 3.26±0.03 days.

* Supplied by the Y-12 plant, Carbide and Carbon Chemicals Corporation, through the Isotopes Division, U. S. Atomic Energy Commission, Oak Ridge, Tennessee.

Z2. Beta- and Gamma-Radiations of Arsenic[16]. C. S. Wu, W. W. Havens, Jr., and L. J. Rainwater, *Columbia University.*—A source of Arsenic AS^{76} obtained from the Oak Ridge pile was investigated, with respect to its beta- and gamma-rays, by the use of a helical focusing magnetic spectrometer and coincidence counting methods. Gamma-ray energies of the AS^{76} were determined from photoelectric lines produced with a thin lead radiator and also from Compton electrons produced in brass. The energies of the stronger lines are 0.557 and 1.22 Mev. The weak one has energy 1.78 Mev. The beta-ray spectrum was measured with an extremely thin source on a backing of 0.08μ Collodin film. Fermi plot of the data gives three groups with end points which agreed well with the energies of the gamma-rays determined. Beta-gamma coincidences were also measured. A scheme of disintegration will be proposed. A search for positrons put the upper limit of the number of positrons less than 0.1 percent of that of electrons. This document is based on work performed for the Atomic Energy Commission.

Z3. Radiations from the Long Period Activity of Zirconium.* M. V. Scherb and C. E. Mandeville, *Bartol Research Foundation.*—The 63-day activity was induced in zirconium hydroxide, irradiated by slow neutrons in the Clinton pile. Chemical purification was carried out for the removal of calcium, iron, and phosphorous as possible impurities. The beta rays of Zr^{95}, separated from its daughter elements of columbium, had a maximum energy of 0.40 Mev, measured by aluminum absorption. The maximum energy of the gamma-rays was 0.91 Mev as measured by coincidence absorption. The beta-gamma coincidence rate was 0.21×10^{-3} coincidence per beta-ray, independent of the beta-ray energy, suggesting a simple spectrum. The gamma-gamma coincidence rate, greater than the beta-gamma coincidence rate, was $(0.29\pm0.02)\times10^{-3}$ coincidence per gamma-ray. A comparison of these coincidence rates with those of Sc^{46} shows that the 0.91 Mev gamma-ray is non-coincident with the beta-rays and may be related to some other decay process. This in turn suggests the possibility of a confusion of isotopic assignments in the zirconium region.

* Assisted by the Office of Naval Research.

Z4. Radioactive Ru and Tc. D. T. Eggen* and M. L. Pool, *The Ohio State University.*—During a detailed study of the reported radioisotopes of Ru and Tc, a new isotope of Ru and one of Tc were found by bombarding Mo with alpha-particles. The Ru activity decays with a half-life of 1.65±0.05 hours and emits 1.1-Mev positrons, 0.7-A x-rays and 1.05-Mev gamma-rays. Fast neutron bombardment of Ru also produces this activity. The Tc activity decays with a period of 20.0±0.5 hours and emits 0.7-A x-rays and 0.76-Mev gamma-rays. The Tc activity also is produced by proton bombardment of Mo and as a daughter product of the 1.65-hour Ru activity. Using electromagnetically separated isotopes,[1] alpha-bombardments were made on Mo^{92}, enriched to 92 percent abundance, and Mo^{94}, enriched to 75 percent abundance. This made possible the assignment of the 1.65-hour and 20-hour activities to Ru^{95} and Tc^{95}, respectively. In addition, it is possible to definitely assign the reported[2] 2.8-day Ru activity to Ru^{97}.

* Research Fellow of the National Institute of Health.
[1] Supplied by the Y-12 plant, Carbide and Carbon Chemicals Corporation through the Isotope Division, United States Atomic Energy Commission, Oak Ridge, Tennessee.
[2] W. H. Sullivan, N. R. Sleight, and E. M. Gladrow, Phys. Rev. 70, 778 (1946).

Z5. Nuclear Isomers Produced by Slow Neutron Capture. M. Goldhaber and C. O. Muehlhause, *Argonne National Laboratory.*—A systematic investigation of nuclear isomers produced by slow neutron capture has been under way for some time. Some of the results are the following: The 48-minute isomeric transition in Cd is assigned to Cd^{111*} by observing the (n,γ) reaction in enriched Cd^{110}. The 17.5-sec. isomeric transition in Se is assigned to Se^{77*} by observing the (n,γ) reaction in enriched Se^{76}. Thus for both Cd and Se the metastable state is assigned to an odd mass nucleus in agreement with Mattauch's rule. The 72-sec. In^{114} isomer is produced by bombarding enriched In^{113} with thermal neutrons. The partial isotopic cross section is found to be $(2\pm0.3)\times10^{-24}$ cm^2, ~3 percent of the capture cross section of In^{113}. The metastable state of Cs^{134} is assigned to the 3-hour period. Internal conversion electrons as well as characteristic Kα radiation of Cs are observed. The energy of the transition is ~160 kv. The internal conversion electrons from the 6.6 min. isomeric transition in Cb^{94} have been observed, as well as characteristic Kα radiation of Cb. The energy of the transition is found to be ~50 kv. It leads to a long-lived ground state, the activity of which has so far not been detected ($T\gg100$ years).

Z6. Cloud-Chamber Measurements of Cadmium Capture Gamma-Rays. C. D. Moak and J. W. T. Dabbs, *Oak Ridge National Laboratory* (*Introduced by E. O. Wollan*).—A study of the capture gamma-rays from cadmium has been made by measuring the energy of the pairs produced in a 0.008 cm. Pb radiator in a cloud chamber operated in a magnetic field of about 1400 gauss. To reduce the errors arising from scattering, the chamber was filled with helium at a pressure of 3 atmospheres. About 30,000 stereoscopic photographs have been taken which have yielded some 400 acceptable pairs. The pair distribution *versus* energy plot, and the corresponding gamma-ray intensity *versus* energy curve will be presented. Measurements so far made on about 100 pairs show a peaking of the gamma-ray intensity at about 5 Mev.

Z7. Separation of the Isomers of Indium 112 and Indium 114 in an Electric Field.* G. J. GOLDSMITH, *Purdue University.*—It has been shown[1] and confirmed that chemical changes induced in a molecule by the isomeric transition of one of its nuclei produce ions which can be collected on an electrode placed in a non-conducting solution of the compound. Indium 114 dissolved in chloroform as the 8-hydroxy quinolate was subjected to a field of the order of 8000 volts per centimeter between nickel electrodes (2×3 cm.) spaced about 1 or 2 mm. apart for various periods up to twenty minutes. The deposit on the anode was found to have the expected half life of 72 seconds superimposed on a weak background of the long lived upper state. Similarly, in the case of the In^{112} isomers, the 9 minute period of the ground state was found confirming the growth curve analysis of Smith, Tendam and Bradt.[2]

* Supported by the Office of Naval Research.
[1] Capron, Stokkink, and van Meerssche, Nature **157**, 806 (1946).
[2] Smith, Tendam, and Bradt, Phys. Rev. **72**, 1118 (1947).

Z8. Gamma-Radiation from Tellurium and Samarium. J. M. CORK, R. G. SHREFFLER, AND C. M. FOWLER, *University of Michigan.*—As a result of the many previous investigations on tellurium it had been concluded that, from the 8 known stable isotopes, 8 radioactive emitters, consisting of four sets of isomers, existed. A sample of metallic tellurium given a particularly long exposure in the Oak Ridge pile fails to show certain of the activities that might be expected. Only two long-lived emitters appear to be present, with half-lives of 8 days and 144 days. The 8-day activity is undoubtedly due to iodine 131. The 144-day activity previously ascribed to tellurium 121 is believed to be an excited state of one of the stable isotopes. This conclusion is based both on its mode of formation and the nature of its radiation. Several conversion electron groups are observed, indicating gamma-energies of 87, 108, and 157 kev. Other higher energy gamma-radiation is revealed by absorption. The K−L−M differences in certain of the conversion groups are characteristic of tellurium and not of antimony as would be expected if K capture or positron emission occurred first. In a samarium sample given a similar long exposure, a short lived (47-hr.) activity is observed which yields a converted gamma-ray of energy 102.1 kev. Terbium is present in most of the rare-earth elements with its strongly converted gamma-radiation of half-life 74 days. An additional samarium activity of longer half-life, emits a gamma-ray of energy 242.4 kev which is converted.

Z9. Internal Conversion Electrons Accompanying Slow Neutron Capture in Gd. O. SALA,* P. AXEL, AND M. GOLDHABER, *University of Illinois.*—Amaldi and Rasetti[1] have observed that approximately one internal conversion electron of an energy of ~70 kev is emitted for each slow neutron captured in Gd. They attempted to find, by a mechanical method, whether the electron is delayed and found an upper limit for the mean lifetime of 10^{-3} sec. We have resumed these attempts with an electronic method in the following way: Neutrons from a Po−α−Be source are slowed down in paraffin. The capture gamma-rays emitted when the slow neutrons are absorbed by Gd are recorded by a gamma-ray Geiger counter. The pulse from this counter sets off a fast sweep (0.2 microsec./inch) on an oscilloscope. The internal conversion electrons are recorded with a thin mica end window Geiger counter. The pulse from this counter produces a vertical deflection. The trace is intensified only when the two events occur within a microsecond. This makes photographic recording possible. In this way we find that the internal conversion electron of Gd is emitted with a mean lifetime $<10^{-7}$ sec. relative to the capture gamma-rays.

* Rockefeller Fellow of the University of São Paulo, São Paulo, Brazil.
[1] E. Amaldi and F. Rasetti, Ricerca Scient. **10**, 115 (1939).

Z10. Radioactive Eu, Gd, and Tb. N. L. KRISBERG AND M. L. POOL, *Ohio State University,* AND CARL T. HIBDON, *University of Colorado.*—An 18.0-hour period and a weaker 5.5-day period have been produced by neutron bombardment of gadolinium resulting in a saturation intensity ratio of 25. A deuteron bombardment of gadolinium gave a ratio of 3. The 18.0-hour period decays by emission of negatrons of 0.85 Mev and a γ-ray of approximately 0.3 Mev. The 5.5-day period decays by emission of negatrons of 0.5 Mev and γ-rays of 1.28 Mev. Neither period is produced by fast neutron bombardment of Tb but there is some evidence that both are produced by fast neutron bombardment of Dy. Accordingly the 18.0-hour and 5.5-day periods are tentatively assigned Gd^{161} and Tb^{161}, respectively. The 62-day and 22-year periods have been produced by a deuteron bombardment of europium. The latter figure has been estimated from observations extending over five years. The decay is by emission of negatrons of 0.9 Mev and by γ-rays. The 62-day period is probably attributable to Gd^{153} and the 22-year period to Eu^{154}.

Z11. The Beta- and Gamma-Radiation of W^{187} and Au^{198}.* ROGER G. WILKINSON AND CHARLES L. PEACOCK, *Indiana University.*—The radiation of W^{187} produced both by deuteron and neutron bombardment has been re-investigated.[1] The beta-ray spectrum consists of two groups with end points at 0.63 and 1.33 Mev. Four gamma-rays are observed with energies of 0.69, 0.62, 0.48, and 0.21 Mev. There is some evidence of another gamma-ray at 0.14 Mev, but owing to strong counter window cut-off in this region, the presence of this and other low energy gamma-rays reported by Valley[2] cannot be substantiated. A tentative decay scheme for W^{187} will be proposed. Our determination of the radiations from Au^{198} are in good agreement with that of Siegbahn.[3] The beta-ray spectrum appears simple with an end-point at 0.97 Mev, each beta-ray being followed by a 0.41 Mev gamma-ray. The gamma-ray is converted with a K conversion coefficient of 2.5 percent.

* Supported by the Office of Naval Research.
[1] Schwartz and Pool, Phys. Rev. **71**, 122 (1947).
[2] Valley, Phys. Rev. **59**, 686 (1941).
[3] Siegbahn, Proc. Roy. Soc. **189**, 527 (1947).

Z12. A Study of the Radiations of Two Radioactive Isotopes of Iridium.* C. E. MANDEVILLE AND M. V. SCHERB, *Bartol Research Foundation.*—The nineteen-hour

activity of Ir^{194} was induced in IrO_2, irradiated by slow neutrons for thirty minutes in the Clinton pile. Coincidence absorption experiments disclosed the presence of a gamma-ray of energy 1.43 Mev. A momentum distribution of secondary electrons ejected from a thick aluminum radiator in a magnetic spectrograph indicated an energy of 1.35 ±0.03 Mev. The beta-gamma coincidence rate corrected for the presence of Ir^{192}, decreased from 0.06×10^{-3} coincidence per beta-ray at zero absorber thickness to zero at 0.150 g/cm². An inner beta-ray group, coupled with gamma-rays, then has an end point at 0.48 Mev. The 2.2 Mev beta-rays are non-coincident with gamma-radiation. A gamma-gamma coincidence rate of $(0.54\pm0.05)\times10^{-3}$ coincidence per gamma ray was also present in Ir^{194}. The 68-day activity of Ir^{192} was found to emit beta-rays of energy 0.56 Mev. The beta-gamma coincidence rate was 0.41×10^{-3} coincidence per beta-ray, suggesting a simple spectrum and agreeing with an earlier report.[1] A gamma-gamma coincidence rate of $(0.23\pm0.01)\times10^{-3}$ coincidence per gamma-ray was also observed. The beta-gamma coincidence rate suggests that each beta-ray is followed by 0.6 Mev of gamma-ray energy.

* Assisted by the Office of Naval Research.
[1] M. L. Wiedenbeck and K. Y. Chu, Phys. Rev. 72, 1164 (1947).

SUPPLEMENTARY PROGRAMME

SP1. Relativistic Field Theories.* T. S. CHANG, *Carnegie Institute of Technology* (*Introduced by F. Seitz*).—In a relativistic field theory, it is important to introduce Schroedinger functionals on any space-like surface and study their changes as the surface changes, as recently pointed out by Dirac. We consider here fields $q(x)$ satisfying the usual Lagrangian principle. Let S be any surface, (u_1, u_2, u_3) its curvilinear coordinates, and let $\langle q(u)S|\rangle$ be the Schroedinger functional on it, with the nature of the functions $q(u)$ not specified for the moment. The Schroedinger equation will be

$$\langle q(u)S'|\rangle-\langle q(u)S|\rangle=J\langle q(u)S|\rangle, \qquad (1)$$

where S' is a surface slightly different from S, and J is an operator operating on $q(u)$ and depending on S,S' and the choice of their coordinates. J are found so that (i) (1) is integrable. (ii) If we construct properly the expectation value of q at a point P from $\langle q(u)S|\rangle$, S being a surface passing through P, the expectation value is independent of choice of S and its coordinates u, and satisfies the required field equations. The special cases in which S are planes and J are simply related to the energy momentum tensors or angular momentum tensors are studied.

* To be given after Session E if the Chairman grants time.

SP2. An Explicit Formula for the Energy Levels of the Asymmetric Rotator According to Quantum Mechanics.* ENOS E. WITMER, *University of Pennsylvania*.[1]—Starting with the determinant formula given by Dennison[2] for the energy levels of the asymmetric rotator the writer has obtained an explicit formula for the energy in the form of an infinite series. Actually there are two such series, because the domain of variation of the parameters must be divided into two partial domains with one series for each partial domain. These series formulas are the same as those mentioned in Abstract No. Y12, where they were obtained by another method. Due to the relation between the two formulas only one need be used for calculation. The formula is complicated but highly systematized and can be written so that the coefficients after the first one are functions of the quantum numbers alone. There are recurrence formulae for the coefficients. The formulas for many coefficients in this series have been obtained already and many more will be obtained. Numerical tables of the coefficients as functions of the quantum numbers are being calculated in order to make the formula as useful as possible.

* To be given after Session Y if the Chairman grants time.
[1] Supported by Bureau of Ships, Department of the Navy.
[2] D. M. Dennison, Rev. Mod. Phys. 3, 280 (1931).

SP3. A Coincidence Investigation of Lanthanum (140).* C. E. MANDEVILLE AND M. V. SCHERB,[1] *Bartol Research Foundation*.—La_2O_3, irradiated by neutrons in the Clinton pile, was separated into calcium, phosphorous, barium, and lanthanum. The beta-gamma coincidence rate was 1.63×10^{-3} coincidence per beta-ray and appeared to be independent of the beta-ray energy. A strong gamma-gamma coincidence rate, $(0.85\pm0.03)\times10^{-3}$ coincidence per gamma-ray was also present. Using a gamma-ray counter of "low Z" materials and the beta-gamma coincidence rate of Sc^{46} as a calibration point, it was concluded that on the average, each beta-ray is followed by 2.3 Mev of gamma-ray energy. On the other hand, assumption of a detection efficiency independent of the quantum energy leads to the conclusion that two gamma-rays follow each beta-ray, in agreement with the earlier Indiana University report.[2]

* To be given after Session Z if the Chairman grants time.
[1] Assisted by the Office of Naval Research.
[2] A. C. G. Mitchell, L. M. Langer, and L. J. Brown, Phys. Rev. 71, 140 (1947).

SP4. A High Pressure Ion Chamber Using Fast Electron Collection.*, ** H. W. FULBRIGHT AND R. J. BRITTEN, *Princeton University*.—A high pressure ion chamber has been built for use in analyzing the distribution in energy of inelastically scattered protons. Fast collection of electrons in argon gas at pressures up to 50 atmospheres is used. The collector is shielded from the region into which the protons are shot by a "Frisch grid" which has the effect of making all electrons freed along the proton tracks equally effective in carrying current to the collector. Pulses from the chamber are fed through a fast linear amplifier into a ten channel pulse height discriminator of the type designed by Matt Sands. With 40 atmospheres pressure the two peaks from normal uranium alpha particle groups can easily be resolved. Protons can enter the chamber through a 1.5 mil steel window. Curves showing the collection time and pulse height for various pressures and voltages will be shown.

* This work was supported in part by Navy contract.
** To be given after Session X if the Chairman grants time.

Author Index to Papers Presented at the Washington Meeting

Aiken, Howard—No. W1
Alburger, David E.—No. T10
Aldrich, L. T. and Alfred O. Nier—No. I11
Allen, James S., H. R. Paneth, and A. H. Morrish—No. I7
Aller, L. H., C. W. Ufford, and J. H. Van Vleck—No. C1
Allison, S. K., H. V. Argo, W. R. Arnold, L. del Rosario, H. A. Wilcox, and C. N. Yang—No. P6
Alvarez, Luis W.—No. F11
Andrews, C. L.—No. L7
Andrews, Donald H.—No. Q1
Anderson, H. L.—No. N5
Antonoff, George—No. K1
Banks, Floyd R., Jr.—No. B9
Band, William and Lothar Meyer—No. Q7
Bass, Arnold M. and H. Sponer—No. Y13
Bell, P. R. and R. C. Davis—No. X12
Belock, H., E. Bromberg, S. Fifer, U. Manfredi, R. McCoy, and H. Zagor—No. L1
Bender, R. S., F. C. Shoemaker, S. G. Kaufmann, and G. M. B. Bouricius—No. A6
Benedikt, Elliot T.—No. E6
Benedict, W. S.—No. Y8
Bennett, Willard H.—No. H9
Berggren, Jane L. and Robert K. Osborne—No. T8
Bergmann, Peter G.—No. C6
Bershader, D. and R. Ladenburg—No. K9
Beyer, R. T. and J. A. Krumhans—No. B3
Birnbaum, George—No. D11
Bitter, Francis—No. N4
Blair, J. M., William Sleator, Jr., George Freier, E. E. Lampi, and J. H. Williams—No. A3
Blatt, John M.—No. A5
Bless, A. A.—No. C9
Bloom, Evelyn G., Fred L. Mohler, J. H. Lengel, and C. E. Wise—No. H12
Bockstahler, Lester I. and Harmon Plumb—No. Q6
Bonner, T. W., J. E. Evans, J. C. Harris, and G. C. Phillips—No. J10
Borkowski, C. J. and E. Fairstein—No. X6
Borowitz, S.—No. F3
Bottom, Virgil E.—No. G2
Boyer, R. L.—No. H8
Bray, Ralph—No. G3
Brickwedde, F. G.—No. H1
Buechner, W. W., R. J. Van de Graaff, E. N. Strait, C. G. Stergiopoulos, and A. Sperduto—No. J5
Bundy, F. P., A. B. Gregg, and H. M. Strong—No. H7
Burgy, M., D. J. Hughes, and J. Wallace—No. B5
Bush, R. R. and H. W. Fulbright—No. A8
Caldwell, Wallace C. and Lloyd P. Smith—No. B8
Chang, T. S.—No. E10, SP1
Chang, W. Y.—No. S4
Christensen, H. and C. J. Calbick—No. G9
Chupp, W. W., and E. M. McMillan—No. F10
Clark, C. L.—No. X4
Cohen, Martin J.—No. X8
Coles, D. K.—No. V4
Cook, C. Sharp and Langer, Lawrence M.—No. T14
Cork, J. M., R. G. Shreffler, and C. M. Fowler—No. Z8
Courant, E. D.—No. J3
Critchfield, Charles L.—No. A4
Curtiss, L. F.—No. R5
Dailey, B. P., K. Rusinow, R. G. Shulman, and C. H. Townes—No. Y3
Darrow, K. K.—No. M1
Davis, Luther, Jr., and Carroll W. Zabel—No. D10
Davis, W. H., A. O. Williams, Jr., and R. T. Beyer—No. C3
Davison, Perry W.—No. P5
Davisson, Charlotte M. and Robley D. Evans—No. T3
Davisson, J. W.—No. G5
De Felice, Joseph—No. X11
Dempster, A. J.—No. I12
Dresden, M.—No. Q9
Eckert, W. J.—No. W3
Eggen, D. T. and M. L. Pool—No. Z4
Eggler, C., D. J. Hughes, and C. Huddleston—No. T5
Eisenbud, L.—No. A9
Everhart, Edgar, and Sanborn C. Brown—No. D2
Falk, C. E., E. Creutz, and F. Seitz—No. J4
Farnsworth, H. E.—No. G8
Feer, Daniel B.—No. S10
Feshback, H., J. Eisenstein, and J. S. Schwinger—No. I3
Feynman, R. P.—No. E4
Fireman, E.—No. T1
Fitzpatrick, J. A., Thomas Kankovsky, and William J. Thaler—No. K2
Fluharty, R. G. and Martin Deutsch—No. T13
Follin, James W., Jr.—No. L9
Foner, S. N., A. Kossiakoff, and F. T. McClure—No. H10
Fox, R. E., A. Langer, and J. A. Hipple—No. H11
Fox, F. E. and V. Griffing—No. K5
Franzen, W., I. C. Corong, and W. E. Stephens—No. P8
Friedland, S. S. and A. D. Krumbein—No. X7
Fulbright, H. W. and R. R. Bush—No. A7
Fulbright, H. W. and R. J. Britten—No. SP4
Fuson, Nelson—No. Q2
Gardner, Eugene, and C. M. G. Lattes—No. S1
Garrett, M. W.—No. L6
Gartlein, C. W.—No. C4
Goldhaber, M. and C. C. Muehlhause—No. Z5
Goldsmith, G. J.—No. Z7
Golian, S. E., C. Y. Johnson, and M. Kuder—No. EA7
Good, W. M., E. O. Wollan, and W. A. Strauser—No. I14
Green, J. B. and Howard N. Maxwell—No. C2
Greenberg, J. Mayo and T. H. Berlin—No. X2
Greenfield, M. A.—No. F1
Gugelot, P. C., and M. G. White—No. F2
Halliday, David, and John Wheatley—No. D6
Halpern, I.—No. P9
Hardy, R. C., and R. L. Cottington—No. H2
Harris, S. P., and A. S. Langsdorf, Jr.—No. R6
Havens, W. W., Jr., L. J. Rainwater, C. S. Wu, and J. R. Dunning—No. F5
Heitler, W.—No. S12
Henry, Hugh F.—No. L10
Hereford, Frank L.—No. I10
Herlin, Melvin A., and Sanborn C. Brown—No. D1
Herman, R. C., C. F. Meyer, and H. S. Hopfield—No. U6
Hewitt, William H., Jr.—No. D9
Heydenburg, N. P., C. M. Hudson, D. R. Inglis, and W. D. Whitehead Jr.—No. J7
Hickam, W. M.—No. H13
Hicks, B. L.—No. K14
Hoffmann, Banesh—No. S11
Hoge, Harold J.—No. H4
Hudspeth, E. L. and C. P. Swann—No. J9
Hughes, Arthur L. and Clyde L. Cowan—No. T2
Hughes, D. J. and C. Eggler—No. T6
Humphreys, R. F., and H. T. Motz—No. P1
Hunter, Joseph L.—No. K4
Iberall, A. S. and W. A. Wildhack—No. K11
Inglis, D. R.—No. J8
James, Hubert M.—No. G4
Jen, C. K.—No. Y4
Jenkins, James F., Jr.—No. EA3
Johnson, E. A.—No. B1
Johnson, Peter D. and Ferd E. Williams—No. U5
Judson, L. V.—No. R1
Katcoff, S., J. A. Miskel, and C. W. Stanley—No. I13
Kê, T'in-Sui—No. G10
Kennard, E. H.—No. K12
King, Gilbert W. and R. M. Hainer—No. Y9
Kissinger, C. W. and D. Cooper—No. S6
Kittel, Charles—No. B4, V2
Knable, N., E. O. Lawrence, C. E. Leith, B. J. Moyer, and R. L. Thornton—No. F9
Koehler, J. S.—No. G6

Krisberg, N. L., M. L. Pool, and Carl T. Hibdon—No. Z10
Kusch, P.—No. M3
Ladenburg, R., C. C. Van Voorhis, and J. Winckler—No. K8
Lamb, W. E.—No. M2
Langer, R. M. and Herman Yagoda—No. S9
Langsdorf, Alexander, Jr.—No. F8
Lattes, C. M. G. and Eugene Gardner—No. S2
Lauer, James L.—No. L11
de Launay, Jules and M. C. Steele—No. Q4
Levine, Harold, and Julian Schwinger—N. E3
Ling, D. S. and D. L. Falkoff—No. I6
Lyons, H.—No. R6
Lyons, Harold, George Birnbaum, and S. J. Kryder—No. D3
McCarthy, R. L., J. A. Lockwood, P. J. Rice, and H. L. Schultz—No. X3
McCormack, R. L., J. Cardell, and W. B. Nottingham—No. U1
McCown, D. A., L. L. Woodward, M. L. Pool, and H. L. Finston—No. Z1
McMillan, E. M.—No. A1
Mack, J. E.—No. C5
Mandeville, C. E. and M. V. Scherb—No. Z12, SP3
Marcus, Paul M.—No. K6
Markstein, George H.—No. K13
Marinelli, L. D. and G. J. Hine—No. X13
Marlow, Douglas, C. R. Nisewanger, and W. M. Cady—No. K7
Masi, J. F.—No. H3
Mason, R. C.—No. G12
Maxwell, E., P. M. Marcus, and J. C. Slater—No. Q3
Meggers, W. F.—No. R2
Meyer, Lothar and William Band—No. Q8
Michels, Walter C. and Louise Gaus—No. U3
Miller, P. H., Jr., and J. J. Markham—No. G1
Millikan, R. A.—No. EA1
Moak, C. D. and J. W. T. Dabbs—No. Z6
Morrison, P.—No. I9
Moshinsky, Marcos, and E. P. Winger—No. E5
Motz, H. T., and R. F. Humphreys—No. P2
Nafe, John—No. M4
Nelson, Edward B., and John E. Nafe—No. D4
Nierenberg, W. A. and M. Slotnick—No. Y6
Norris, L. D. and Arthur H. Snell—No. T9
Onsager, L. and J. E. Robinson—No. Q5
Parker, W. L. and J. J. Dropkin—No. U7
Peacock, Charles and Roger G. Wilkinson—No. T12
Peaslee, D. C.—No. I5
Peck, R. A., Jr.—No. P3
Pell, E. M. and D. H. Tomboulian—No. U8
Pensak, L.—U2
Perlow, G. J., E. Krause, and C. Schroeder—No. EA8
Piccioni, Oreste—No. S3
Pietenpol, William J., John D. Rogers, and Dudley Williams—No. Y7
Plyler, E. K. and S. L. Kruegel—No. V10
Pollard, E., V. L. Sailor, and L. D. Wyly—No. P4
Pound, R. V.—No. N3
Rado, G. T., M. Maloof, and H. Rosenblatt—No. B2
Rarita, William—No. I1
Reynolds, S. E., and E. J. Workman—No. L3
Rose, M. E., and M. M. Shapiro—No. E7
Sachs, R. G.—No. I4
Saibel, Edward—No. G11
Sala, O., P. Axel, and M. Goldhaber—No. Z9
Sanderson, J. A., J. A. Curcio, and Dorothy Estes—No. H5
Sands, Matthew—No. S8
Sard, R. D. and A. H. Benade—No. S5
Schelberg, A. D., M. B. Sampson, and A. C. G. Mitchell—No. T4
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Snyder, R. L.—No. W2
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Strandberg, M. W. P.—No. V5, Y2
Strong, H. M., and F. P. Bundy—No. H6
Studer, Frank J. and Gorton R. Fonda—No. U4
Swann, C. P. and E. L. Hudspeth—No. X5
Swann, W. F. G.—No. EA6
Szilard, L., S. Bernstein, B. Feld, and J. Ashkin—No. F4
Taub, A. H.—No. K15
Teichmann, T.—No. I2
Tisza, L.—No. E9
Tomlinson, E. P.—No. L4
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Van der Grinten, W.—No. X10
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Wildhack, W. A.—No. K10
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Wilson, E. Bright—No. V6
Winckler, John—No. EA2
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Witmer, Enos E.—No. V12, SP2
Woffenstein, Lincoln—No. I8
Woodward, W. M. and I. Halpern—No. J2
Woolley, Harold W.—No. Y11
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Wu, C. S., W. W. Havens, Jr., and L. J. Rainwater—No. Z2
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Ladies wishing to go to the White House on April 29th (see page 4) must write to Mrs. F. G. Brickwedde, National Bureau of Standards, Washington 25, D. C., early enough for their letters to reach her by April 27th.

Please cut along this line

(To be sent to Dr. Hugh Odishaw, National Bureau of Standards, Washington 25, D. C.)

I EXPECT to attend the dinner of the American Physical Society at seven o'clock on Thursday evening, April 29. I enclose a check for ..... places at $5 per place.

(*Name*).....

(*Address*).....

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